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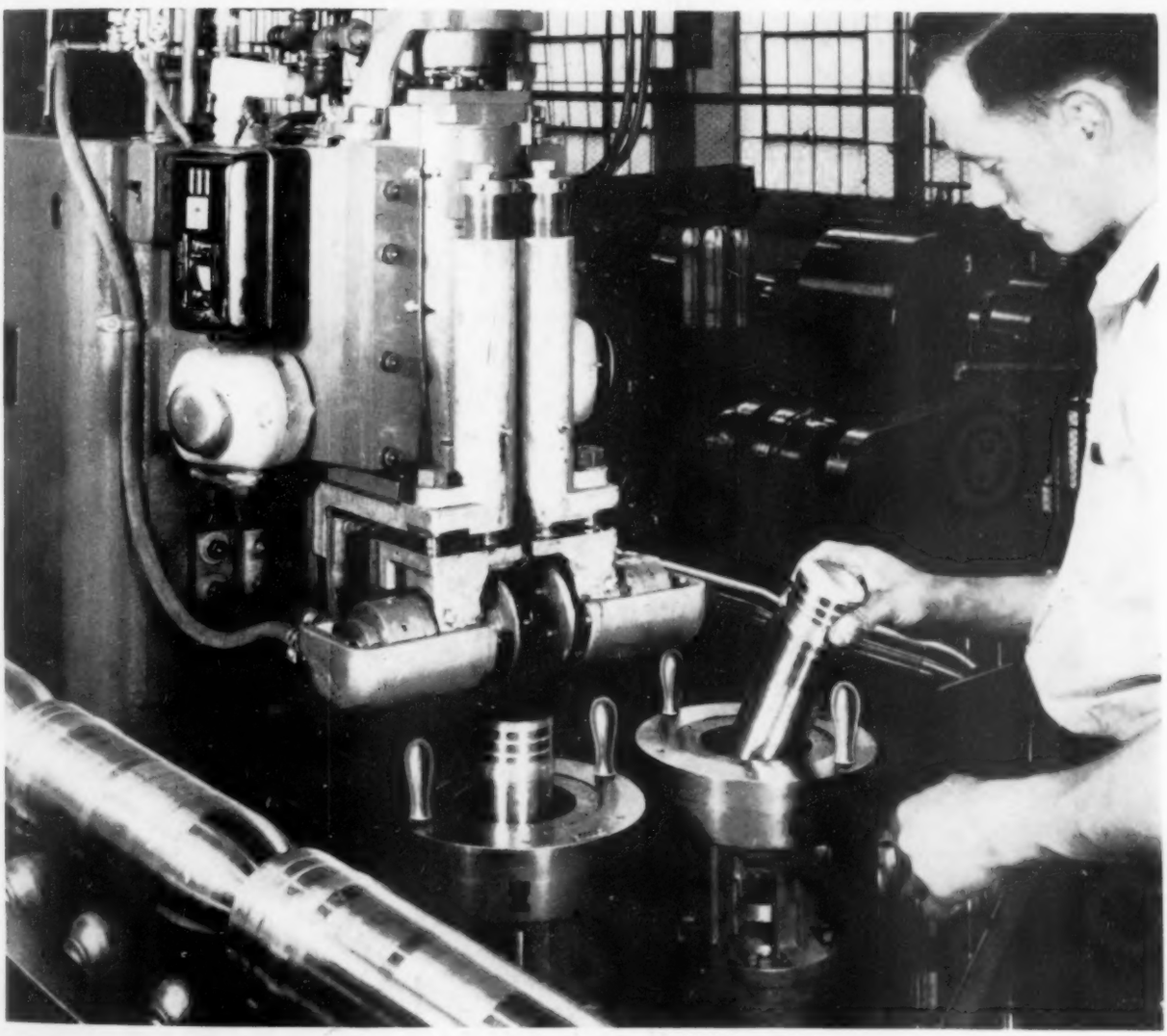

The Journal of the American Welding Society

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Manual and Machine Flame Grooving*

By E. V. David†

Definition

THE oxyacetylene cutting process has two main subdivisions: flame cutting and flame machining. These differ mainly in that in flame cutting the cut penetrates or severs the work, while in flame machining the cut does not penetrate the work, but merely desurfaces it. The distinguishing features of the two processes is illustrated diagrammatically in Fig. 1.

The flame grooving process, which is the subject of this discussion, is a major branch of flame machining. Flame grooving sometimes is also called flame gouging. Similar to oxyacetylene cutting, flame grooving of ferrous metals is a process of preheating the material to be removed to its kindling or ignition temperature and, then, rapidly melting, oxidizing and washing it away, by means of a closely regulated jet or stream of oxygen, issuing from a cutting torch. It is primarily a chemical process, based on the remarkable chemical affinity of oxygen for ferrous metals, when at and above their kindling temperatures. In the case of plain carbon steels, the metal is preheated to approximately 1400 to 1600° F., which in daylight is a bright red color. Only the metal in the direct path of the oxygen jet is acted upon, to form a groove or gouge. Under skilled workmanship, flame grooving tolerances may be held within close limits. The groove walls are smooth and of uniform cross section and contour.

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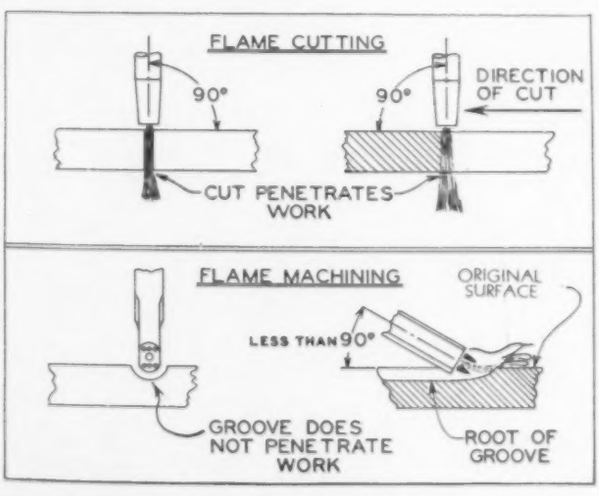


Fig. 1—Diagram Illustrating Basic Difference Between Flame Cutting and Flame Machining

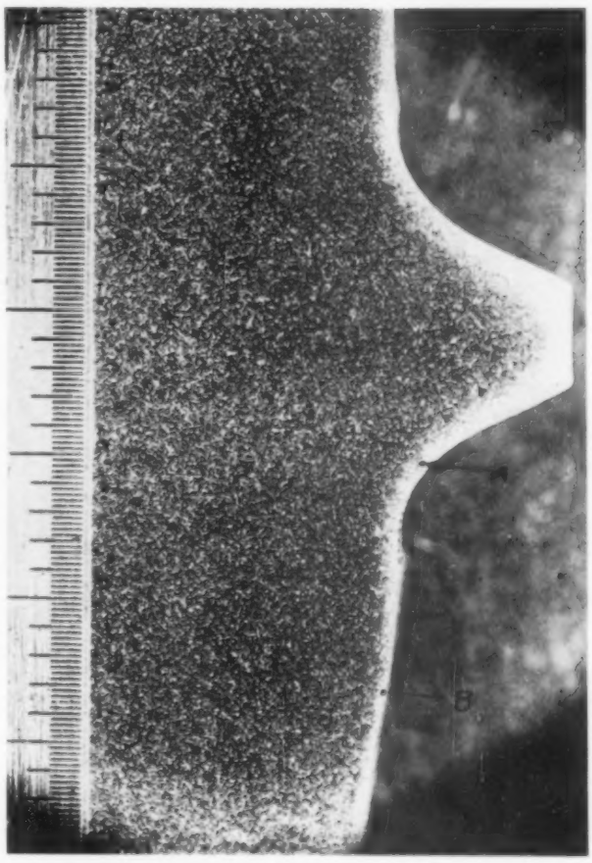


Fig. 2—Photograph (3X Magnification) of Double J-Grooved Edge of 2 In. Plate, Prepared by Flame Grooving and Flame Cutting

Chemistry

Oxidation of Iron

The oxide of iron formed in flame grooving is a black, brittle substance, identical in composition with *hammer scale or magnetite* ore. Its chemical formula is Fe_3O_4. The completed equation for the oxidation reaction in flame grooving is:

$$3Fe + 2O_2 = Fe_3O_4 + 26{,}691 \text{ calories} \qquad (1)$$

In other words, three atoms of iron combine with two molecules of oxygen to produce one molecule of magnetite. In this oxidation reaction, 1593 calories per gram, or 2870 Btu. per lb., of iron are produced, which represent

Fig. 3—Photomicrograph (50X Magnification) of Flame-Grooved Edge at *A* (Fig. 2)

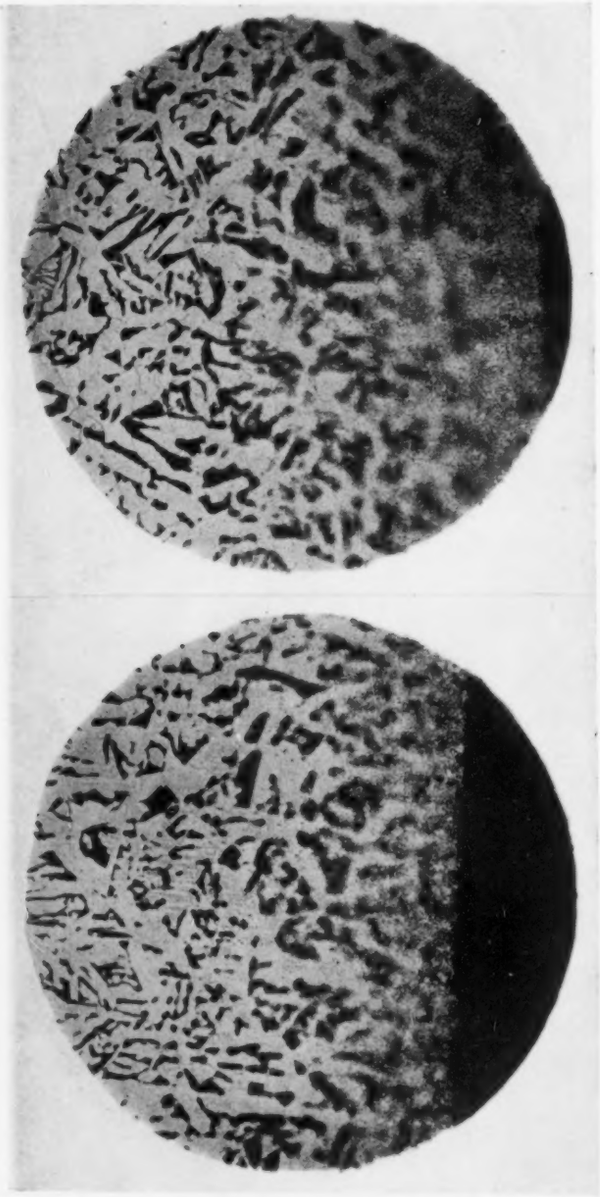


Fig. 4—Photomicrograph (50X Magnification) of Flame-Cut Edge at *B* (Fig. 2)

the calorific energy of the iron. From this it can be computed that, theoretically, 1 lb. oxygen will oxidize 2.618 lb., or 9.186 cu. in., of pure iron, or 1 cu. ft. oxygen will oxidize 0.217 lb., or 0.761 cu. in. of pure iron. In actual flame grooving, the iron or steel removed is not entirely oxidized or consumed by the oxygen, but, due to the eroding effect of the oxygen jet, some of the material is washed out of the groove as unconsumed or metallic iron.

Combustion of Acetylene

Acetylene is the most widely used fuel gas for flame grooving. The chemical equation for its complete combustion is:

$$C_2H_2 + 2^1/_2\ O_2 = 2CO_2 + H_2O + 542{,}700\ \text{Btu.} \quad (2)$$

Expressed otherwise, one molecule of acetylene unites with $2^1/_2$ molecules of oxygen to form two molecules of carbon dioxide and one molecule of water vapor, with a liberation of 542,700 Btu. of heat. The highly endothermic property of acetylene is one reason for its unusual calorific power.

Effect on Steels

In flame grooving, a slight depth of metal immediately adjacent to the groove face is raised to a temperature considerably above the critical range. As the groove progresses, the steel cools again through this range, with a speed dependent upon the heat conductivity of the surrounding metal, radiation losses and the forward motion of the torch. Usually the rapidity of cooling is sufficient to have a chilling or quenching effect on the groove edges, especially where large masses of cold metal are involved.

Specimens taken from flame grooves show, when polished and etched and examined under the microscope, that the material is not changed chemically, but only in its crystalline grain structure. The normal pearlitic steel is transformed into one or more of several structures, depending on its chemical composition and the rate of cooling. Also, an alteration in grain dimension at the groove edge is induced.

Figure 2 is a photograph (3× magnification) of a double J grooved edge mild steel plate, prepared by flame grooving and flame cutting. It will be noted that the heat-affected zone at the flame-grooved edges, on either side of the land at the center, is approximately twice as deep as that of the flame-cut edges, which form the straight sections of the J groove. While the flame-grooved edges show a heat-affected zone about $^1/_{16}$ in. deep, the flame-cut edges show one about $^1/_{32}$ in. deep.

Figure 3 is a photomicrograph (50× magnification) of the flame-grooved edge at *A*, Fig. 2. This shows a low carbon martensitic structure adjacent to the cut surface. The normal pearlitic structure of the steel plate is seen at the left, away from the cut. A zone of transition lies between the two.

Figure 4 is a photomicrograph (50× magnification) of the flame-cut edge at *B*, Fig. 3. This is similar to Fig. 3, except that the heat-affected zone is only about one-half

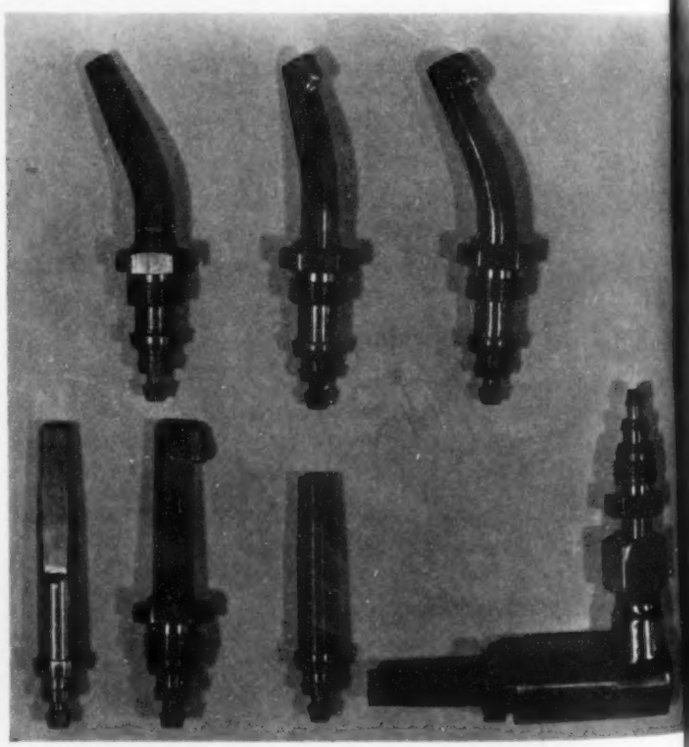


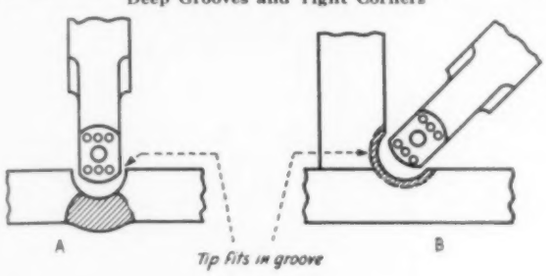
Fig. 5—Flame Grooving Tips and 90° Torch Adapter

as deep. Hardness measurements taken at *A* and *B*, indicated the hardness at both points, was about 165 Brinell.

Flame grooving of carbon steels, containing less than 0.35% carbon, at atmospheric temperatures is not detrimental. In fact, the edges of flame grooves in such materials have physical properties equal or superior to planed, milled or otherwise mechanically prepared grooves. Flame grooving of low and mild carbon steels is permitted by the great majority of codes and specifications.

Where plate edges are flame grooved and later are welded together, either by oxyacetylene or electric arc process, the heat of the welding operation acts to dissolve all previously formed marginal structures and anneals the metal for a considerable depth below the groove surface. Any change in structure that the preceding grooving operation may have produced, in and adjacent to the groove surface, therefore, is obliterated.

Fig. 6—Illustrating How Flat Sides of Tip Make It Possible to Work in Deep Grooves and Tight Corners



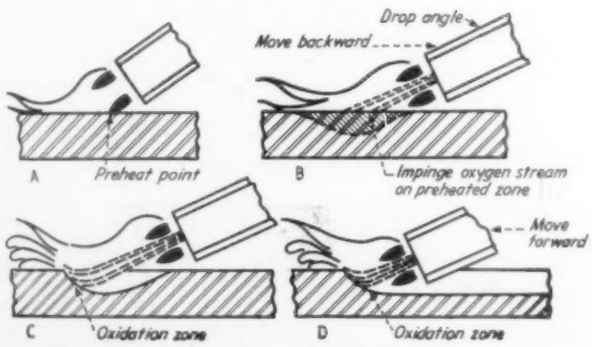


Fig. 7—Diagram Showing Positions Taken by Grooving Tip in Starting a Progressive Manual Flame Groove

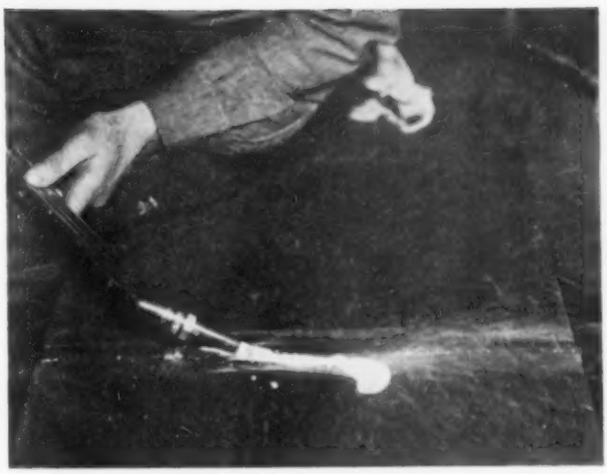


Fig. 8—Progressive Manual Flame Grooving in Progress

Flame grooving of higher carbon and alloy steels, particularly at room temperature, may produce a thin layer of hard material on the groove surfaces which may not be sufficiently ductile to withstand the stresses set up in cooling, or imposed by subsequent service, without cracking. Such cracks are apt to develop into fractures and result in failure of the part.

Experience has shown that, if these higher carbon and alloy steels are properly preheated and, in certain cases, post annealed, no cracks will occur on the flame-grooved edges. Some steels may be preheated to as high as 1000° F. or more for flame grooving, but care should be taken not to carry the preheating too far. To obtain the most efficient use of the oxygen and, at the same time, leave the steel in the best condition, a preheat temperature of 500–600° F. ordinarily should suffice for carbon steels.

Advantages

Flame grooving has a number of distinctive advantages, as compared with mechanical chipping, planing and other methods of performing the same work. These may be enumerated as follows:

Speedy.—Flame grooving is done at a speed of 1 to 4 linear feet per minute. This is several times the speed of competitive processes.

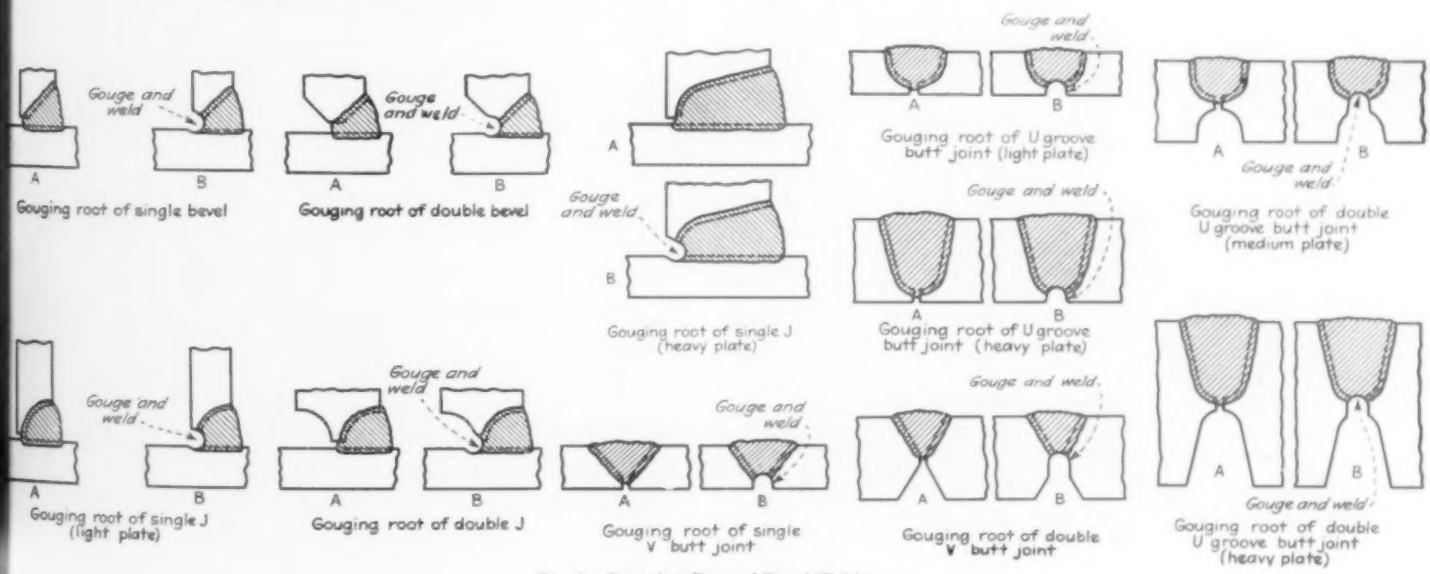

Gouge and weld
A
B
Gouging root of single bevel
Gouging root of double bevel
Gouging root of single J (heavy plate)
Gouging root of U groove butt joint (light plate)
Gouging root of U groove butt joint (heavy plate)
Gouging root of double U groove butt joint (medium plate)
Gouging root of single J (light plate)
Gouging root of double J
Gouging root of single V butt joint
Gouging root of double V butt joint
Gouging root of double U groove butt joint (heavy plate)

Fig. 9—Grooving Root of Bevel Welds

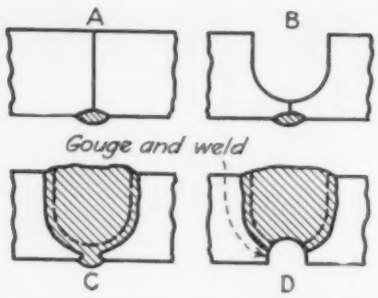


Fig. 10—Procedure for Butt Welding Light Plates

Accurate.—A tolerance of $^1/_{16}$ in. in manual flame grooving and $^1/_{32}$ in. in machine flame grooving on width and depth can be maintained, when correct technique is used. Surfaces are smoother and contours more accurate than those obtained by comparable methods.

Quiet.—The disagreeable din and vibration which inevitably accompany pneumatic and mechanical chipping methods are entirely absent. Therefore, better working conditions are provided.

Portable.—Flame grooving employs the same lightweight, portable apparatus as used for oxyacetylene cutting. Hence, it can be quickly set up in the shop, yard or in the field. Hardly any flame grooving job is out of reach of the process.

Economical.—Naturally a process that is several times speedier than those formerly employed for the same work tends to be more economical. Further, where chipping hammers are employed, constant resharpening of the chisels is necessary. This costly conditioning is eliminated by use of the oxygen stream, the cutting ability of which never is dulled so long as pressures are maintained. Flame grooving tips are provided with standard cutting tip seats and can be inserted in any suitable cutting torch already available.

Flexible.—The design, compactness and light weight of the flame grooving equipment allow for working in ordinarily inaccessible spaces.

Equipment

Flame grooving equipment consists ordinarily of an ordinary cutting torch, with separable flame grooving tips, oxygen and acetylene hose with connections, oxygen and acetylene pressure regulators and gas cylinders. Pressure regulators usually are equipped with cylinder and working pressure gages. Flame grooving tips are of the expanding-orifice, low-stream-velocity type, with a comparatively large diameter at the exit. Relatively low grooving oxygen pressures are used. The tips fit into the standard cutting torch and are of either straight or bent design. Figure 5 shows six styles of flame grooving tips having comparable oxygen orifices, but with variations in external design to perform different grooving operations. Four of the tips have flat sides.

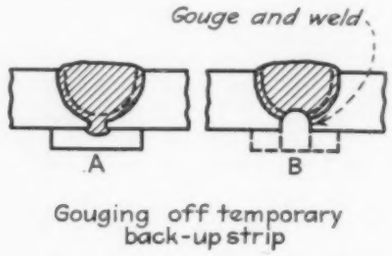


Fig. 15—Removal of Back-Up Strip

Fig. 11—Two ½-In. Plates Butted Together and Tack Welded Before Flame Grooving

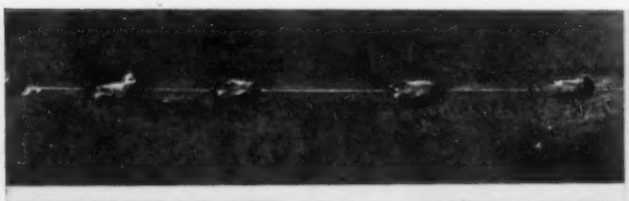


Fig. 12—Same Plates Reversed and U Groove Being Made Along the Joint on Opposite Side from Tack Welds

Fig. 13—U Groove Produced by the Torch Being Arc Welded

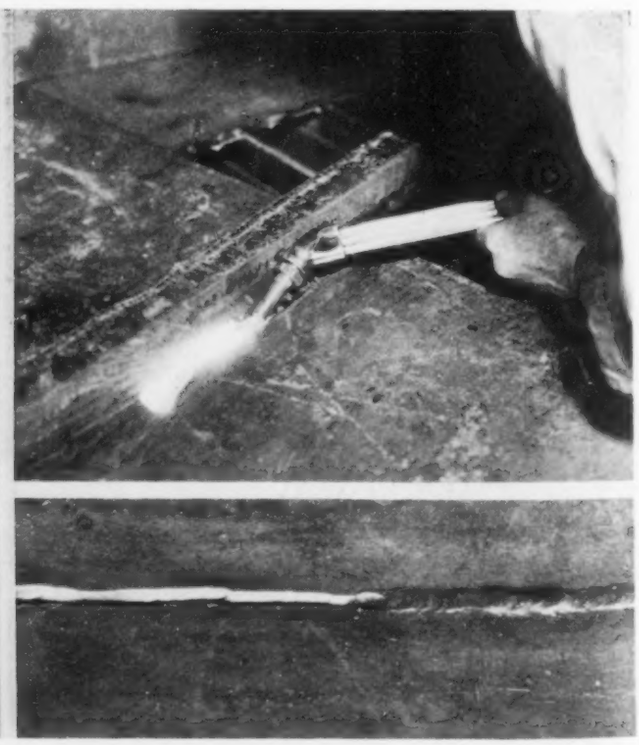


Fig. 14—U Groove Partially Arc Welded

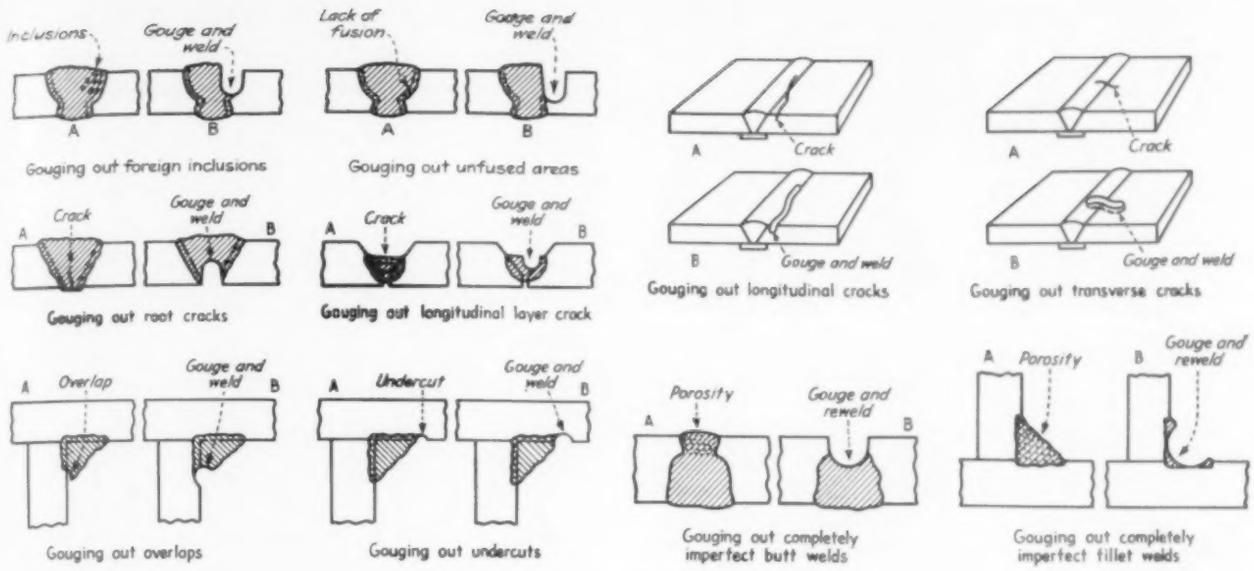


Fig. 16—Removal of Weld Defects

Three have skids of hard metal at the end, used to ride in the groove in certain operations. A 90° adapter for straight machine cutting torches to enable flame grooving of plate edges is also shown. The manner in which the flat sides of these tips make it possible to work in deep grooves and tight corners is illustrated in Fig. 6.

Where larger quantities of oxygen and acetylene are required, gas cylinders often are manifolded. Sometimes acetylene generators are used. For such installations, distribution pipe-lines often are employed to carry both gases to the various points of consumption. In the case of machine flame grooving, the cutting torch is held and operated mechanically, but its essential features remain unchanged.

Controlling Factors

Certain controlling factors apply to all flame grooving whether it is performed manually or by machine. The more important of these are:

Smoothness and Quality.—Cleanliness, smoothness and sharpness of the groove edges, as well as freedom from adherent slag on the adjacent surfaces, are obtained by proper tip positioning, maintaining the proper impingement angle of the oxygen jet and correct gas pressures and grooving speeds. Insufficient oxygen pressure or too high a speed may result in a rippled bottom surface. Excessive oxygen pressure may cause the groove to run out, or be lost.

Groove Dimensions.—Groove width is primarily a function of tip size: so is the radius at the bottom of the groove. Groove depths depend on the angle of the tip to the surface of the work and the oxygen pressure. In the case of multi-pass grooves, the depth depends, of course, on the number of passes also. Table 1 shows approximate groove widths for tips with various exit orifice diameters.

To deepen the groove, the angle of impingement of the oxygen jet, or the oxygen pressure, or both, are increased. To make the groove shallower, the opposite procedure is followed.

Selection of Grooving Tip.—A variety of styles and sizes of grooving tips are available, to suit different jobs. They provide for cutting grooves of various widths and depths and contour in most ferrous materials. They are of different constructions to suit various types and positions of work. They have light or intense preheat flames; the former being suitable for clean new surfaces, while the latter are employed with scaly, rusty or painted surfaces.

Table 1—Approximate Groove Widths for Various Grooving Tips

Tip No.	Exit Orifice Diam., In.	Approx. Groove Width, In.
8	0.128	$^{5}/_{16}$–$^{3}/_{8}$
10	0.161	$^{7}/_{16}$–$^{1}/_{2}$
12	0.221	$^{9}/_{16}$–$^{5}/_{8}$

Theoretically, the heat generated by the oxidation of the material in flame grooving should suffice to make the adjacent metal red-hot, so that, once started, the groove might be continued indefinitely with oxygen only. Actually, the smoothness of this theoretical operation is disturbed by heat conductance of the material, radiation losses and dirt, rust, paint or scale on the surface, so that preheating flames are essential, not only to start the groove, but to carry it on uninterruptedly.

Economic Factors.—The use of oversize grooving tips and excessive oxygen and acetylene pressures is wasteful. For maximum efficiency, grooving tips should be operated at normal gas pressures and grooving speeds which utilize the grooving oxygen jet to best advantage in producing the type of groove desired. Grooving tips should, as a rule, be positioned in the torch to have one group of preheating flames in the groove, with the opposite group above the groove.

Starting Flame Grooves.—In starting flame grooves, the tip is held at the proper angle to the surface, allowing the preheating flames to play on it. When the spot where the groove is to start reaches the kindling temperature, the tip usually is moved backward for a distance of about $^{1}/_{4}$ to $^{1}/_{2}$ in. and the grooving oxygen stream is gradually turned on, impinging on the preheated zone. As soon as oxidation of the metal occurs, the forward motion is started. For certain work "waster" plates are used for starting.

Manual Flame Grooving

Techniques

There are, in general, three different techniques used in manual flame grooving. These are:

1. The progressive technique, in which the groove is made progressively along its length.
2. The step-back technique in which the groove is made in a series of short steps or "bites," the torch being moved backward between each one and then advanced until the groove runs into the already finished section.
3. The spot technique, used for removal of defects in welds and castings and for similar jobs.

Torch Manipulation

In manual flame grooving, the hand-cutting torch is held and guided by the operator steadily but not tightly with the left hand supporting it a few inches back of the head and the right hand on the handle, in position to control the cutting oxygen trigger or lever. As in all manual arts, the results depend largely upon the amount of skill employed. However, the operation is not difficult and the average conscientious workman soon acquires proficiency.

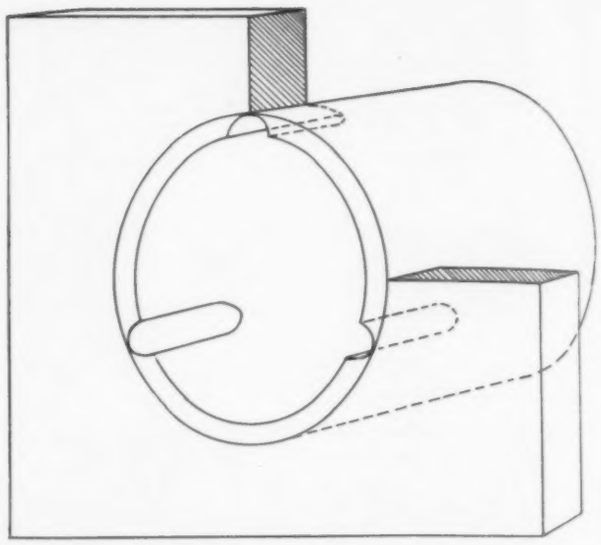


Fig. 20—Removing Tube from Header by Flame Grooving and Collapsing

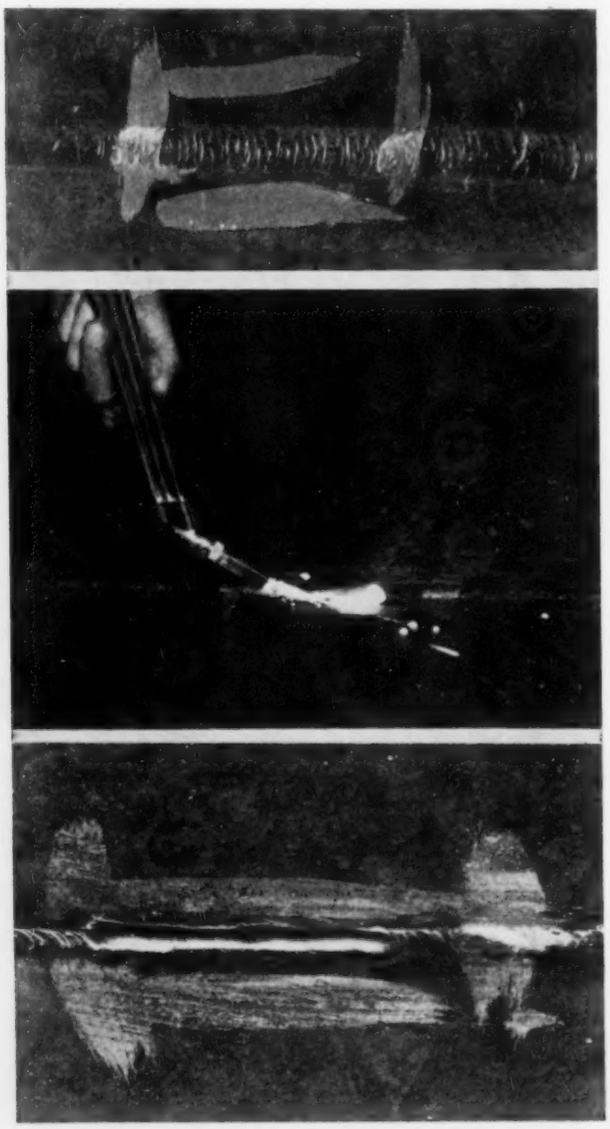


Fig. 17—(Top) Section of Weld Marked for Removal by Inspector, Due to Disclosure of Defect by X-Ray

Fig. 18—(Center) Removal of Defective Weld Section by Spot Manual Flame Grooving

Fig. 19—(Bottom) Defective Weld Section Removed

Starting

In starting the groove, the tip is held at an angle of 30 to 45 degrees to the surface, allowing the inner preheat flame cones to just touch the metal, as shown in Fig. 7 (*A*). As soon as the surface reaches kindling temperature, the angle between the tip and the surface is reduced to 20 to 25 degrees. Simultaneously, the tip is moved backward $^1/_4$ to $^1/_2$ in. and the grooving oxygen stream is gradually turned on, impinging on the preheated zone (see Fig. 7 (*B* and *C*)).

Carrying on the Groove

As soon as oxidation of the metal occurs, the forward motion is started, Fig. 7 (D). Sufficient speed is maintained to keep the slag puddle ahead of the reaction area and to maintain the oxidation (see Fig. 8). If the direction of the groove to be made, or the weld to be removed, is other than a straight line, this path may be followed by gradually swinging the grooving tip in the horizontal plane in the direction required, the same as would be done with a chipping hammer. During this procedure, the angle of the oxygen jet impingement must be held constant, however.

Principal Applications

Removing Roots of Welds

One of the most important applications for progressive manual flame grooving is for removing roots of welds. Many welding codes and specifications for pressure vessels, tanks and other structures require back welds and prescribe that the root of the initial weld must be removed before the back weld is made. In this manner, the most favorable conditions to assure the highest quality of the back weld are provided. With the mechanical chipping hammer, this operation is slow, difficult, noisy and expensive. With manual flame grooving, however, it is

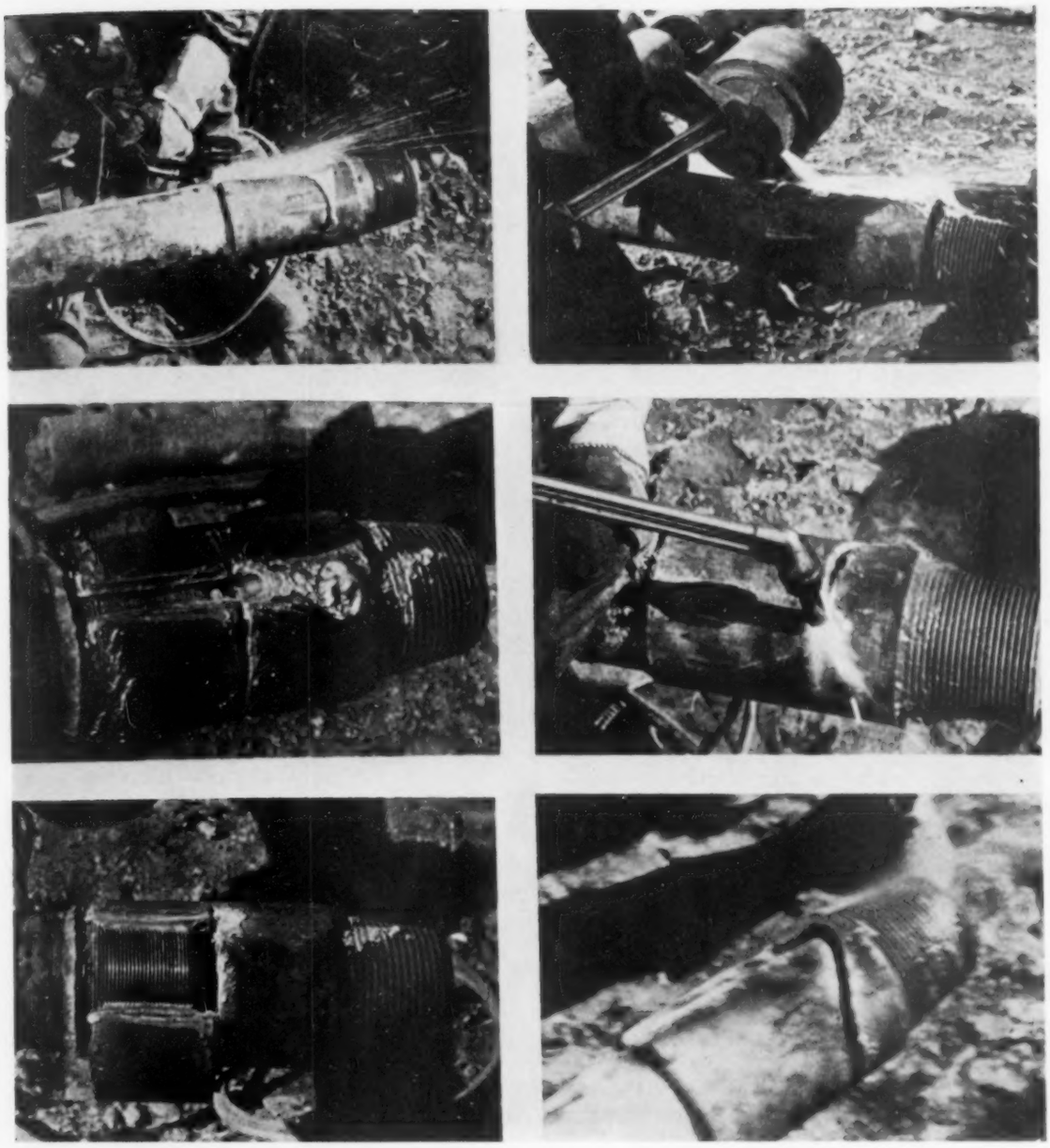


Fig. 21 (Top)—Flame Grooving Welded Tool Joint for Removal

Fig. 22 (Center)—Circumferential Flame Cut Made Half-Way Around Tool Joints. Weld Between Pipe and Joint Washed Off

Fig. 23 (Bottom)—Severed Section of Tool Joint Removed

Fig. 24 (Top)—Flame Grooving Shrunk Fit Tool Joint for Removal

Fig. 25 (Center)—Circumferential Flame Cut Made Half-Way Around Tool Joint

Fig. 26 (Bottom)—Tool Joint Ready for Spreading to Allow Unscrewing

accomplished much faster and easier, in complete quiet and at considerably less expense.

The removal of weld roots from single and double bevel, single and double V, single and double J groove and single and double U groove joints is shown in Fig. 9. Figure 10 illustrates procedure for light or medium weight plates laid out in large areas. The plates are butted edge-to-edge and tack welded, as in *A*. The plates are then turned over and the U groove for welding is made by progressive manual flame grooving, as in *B*. Next the weld is made, as in *C*. The plates are again reversed and the weld root, together with the tack welds, are removed by manual flame grooving, as in *D*. Finally, the back weld is put in.

Figure 11 shows two $^1/_2$-in. plates butted together and tack welded before grooving. Figure 12 shows the same plates reversed and the U groove for welding being made. In this instance, a straightedge is used, to aid in guiding the torch. The slag puddle moves ahead of the reaction zone, leaving the groove reasonably clean. In Fig. 13, the U groove produced by the torch is being arc welded. Figure 14 shows U groove partially arc welded.

Figure 15 shows procedure employed to remove a back-up strip which sometimes is used to aid the penetration of the initial weld. The weld root is removed simultaneously and the joint made ready for application of the back weld.

Removal of Weld Defects

Weld defects, such as inclusions, lack of fusion, porosity, longitudinal and transverse cracks, root and

layer cracks, overlaps and undercuts, are readily removed by spot manual flame grooving. The nature of these defects and the manner of their removal and correction are illustrated in Fig. 16. The grooves made must be of sufficient depth to completely remove the defects and reach sound metal. However, they must likewise be as narrow as possible, consistent with good welding practice, to reduce the amount of rewelding necessary to a minimum. Seams, inclusions and other defects are easily discernible to the flame grooving operator as dark streaks or areas, against the red of the molten zone. In spot grooving, a steeper angle of oxygen jet impingement is employed than in progressive grooving.

Weld defects usually are disclosed by X-ray, gamma-ray, magnetic flux or visual inspection. The spots or areas of weld metal containing these defects are marked for removal by the inspector, frequently as shown in Fig. 17. The removal of this defective section by spot manual flame grooving is shown in Fig. 18. Figure 19 shows defective weld section removed.

Maintenance, Reclamation and Demolition

Manual flame grooving has proved helpful for various types of maintenance, reclamation and demolition work. For example, in maintenance work, defective tubes in boilers, stills and similar equipment, when of sufficient

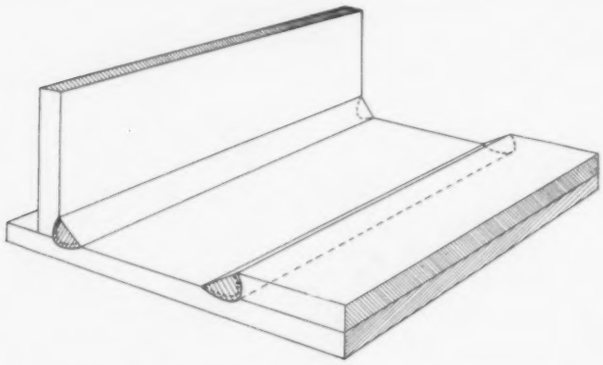


Fig. 27—Removal of Welds by Flame Grooving in Demolition Work

size, may be removed by this process. They are grooved on the inside, at the ends, longitudinally in three or more places around the circumference (see Fig. 20). This facilitates collapsing the tube in the header into which it has been expanded and removing it without damaging the header. A new tube is then installed.

Saving drill pipe by removing tool joints is an example of reclamation work to which manual flame grooving is applicable. In Fig. 21 a welded tool joint is being grooved longitudinally for the length of the thread, which extends about 1 in. beyond the end of the drill pipe on the inside. The tip is held flat and two passes are made to reach the thread tops which, however, must not be damaged. Next, a hole is pierced through the joint and a circumferential cut made half-way around the joint using a cutting tip (see Fig. 22). Then, as also shown in Fig. 22, the weld between the joint and the pipe is washed off all around. Finally the opposite side of the joint is grooved in two passes longitudinally for the length of the thread, to run into the cut, as shown. A good blow with a sledge and blunt chisel will remove the completely severed section of the tool joint, as shown in Fig. 23, leaving the thread on the end of the drill pipe undamaged. The remainder of the weld on the drill pipe is machined off later.

In Fig. 24 a shrunk fit tool joint is being grooved in a

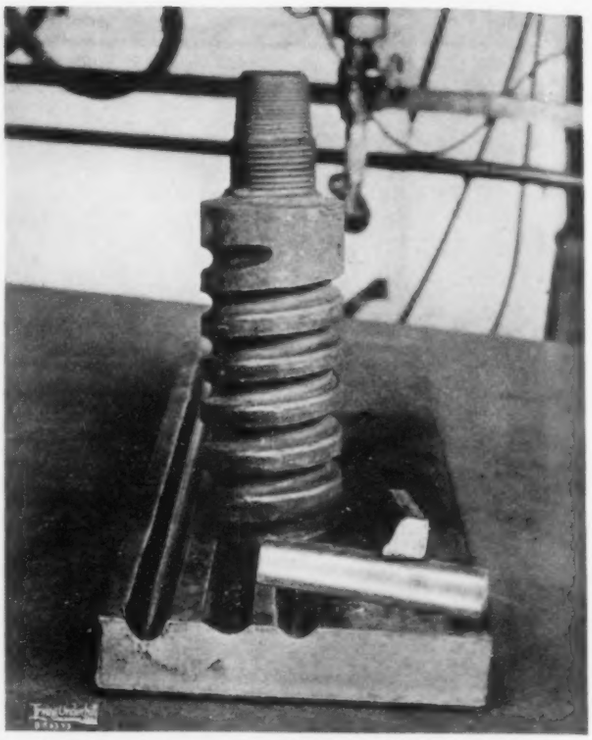


Fig. 28—Assorted Specimens of Various Machine Flame Grooving Operations

manner similar to that already described for the welded tool joint. Figure 25 shows the circumferential cut being made on this joint, also similar to that for a welded tool joint. Figure 26 shows the groove running into the cut. By using a spreading tool, the semi-severed section of the joint is opened up, breaking the thread grip and allowing the joint to be screwed off the drill pipe.

Figure 27 illustrates an example of the removal of welds by manual flame grooving in the demolition of structures of fabricated parts. This procedure frequently is more economical than actually severing the shapes and plates by flame cutting. In addition, a considerable proportion of the component parts can be salvaged and reused for new work.

Machine Flame Grooving

Advantages

For certain flame grooving operations, the substitution of mechanical in place of manual control of the torch effects better workmanship and increased accuracy and

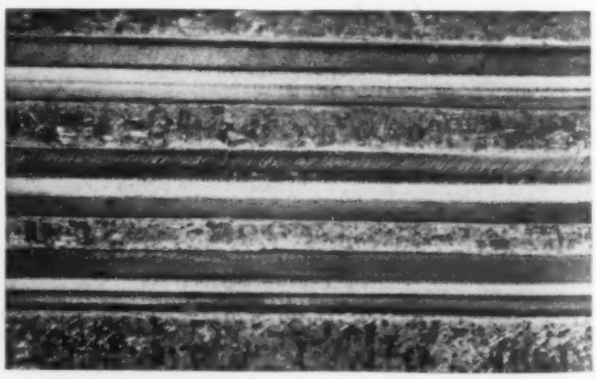


Fig. 29—Accuracy of Machine Flame U-Grooving in Plate Surface

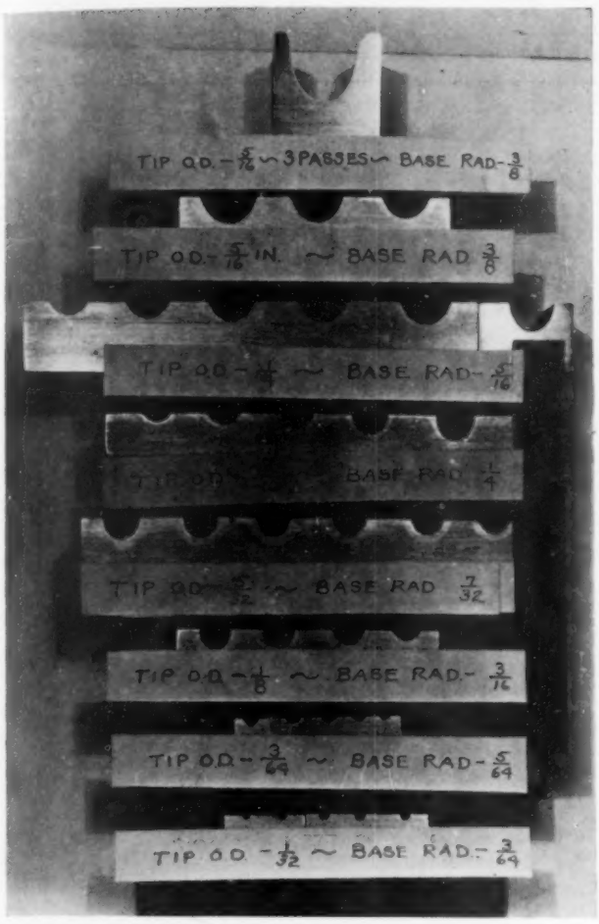

TIP O.D. - 5/32 ~ 3 PASSES ~ BASE RAD. - 3/8
TIP O.D. - 5/16 IN. ~ BASE RAD 3/8
TIP O.D. - 1/4 ~ BASE RAD. - 5/16
TIP O.D. ~ BASE RAD 1/4
TIP O.D. - 9/32 ~ BASE RAD 7/32
TIP O.D. - 1/8 ~ BASE RAD. - 3/16
TIP O.D. - 3/64 ~ BASE RAD. - 5/64
TIP O.D. - 1/32 ~ BASE RAD. - 3/64

Fig. 30—Machine Flame U-Grooved Profiles on Plate Surfaces

economy. The same advantages possessed by machine flame cutting are obtained here also. Frequently, tolerances equivalent to those of rough machining can be maintained.

Types of Operations

In machine flame grooving, the progressive technique is followed exclusively. However, the types of operations performed may be divided into three general classes:

1. U-Grooving of Surfaces.—Under this heading are included U-grooving to any depth in either flat or curved surfaces, and U-grooving of edges of plates butted together.

2. J-Grooving of Edges.—Single J-grooving of edges of lighter plates and double J-grooving of edges of thicker plates are in this category. The grooved edges may be straight or curved, flat or bent.

3. U- or J-Grooving Combined with Bevel Cutting.—This procedure is resorted to where the plates are too thick to allow for edge preparation by U- or J-grooving alone.

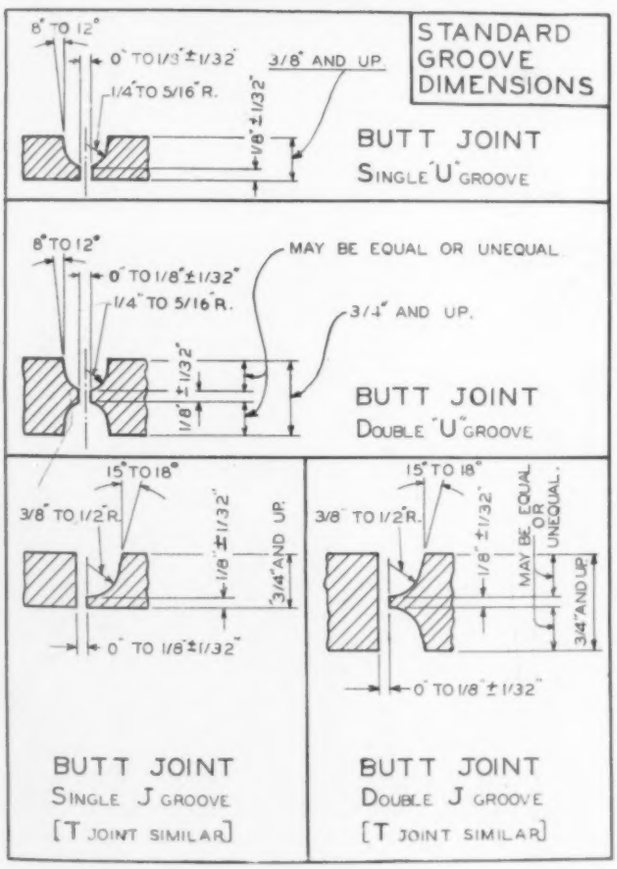
Figure 28 shows assorted specimens of these various machine flame grooving operations, which were prepared in the early experimental stage of the process.

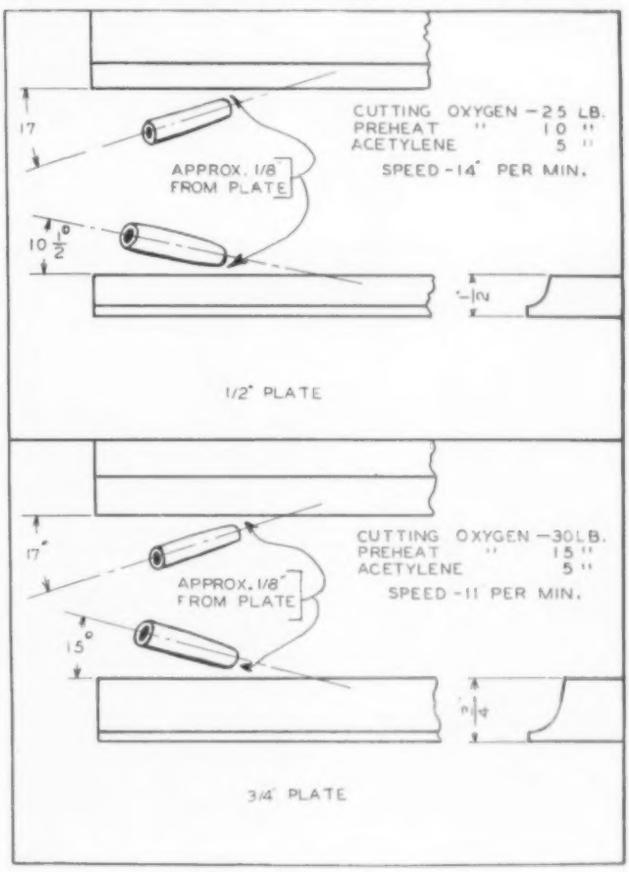
Set-Up Work and Torch

In machine flame grooving, the work can be laid and clamped in a stationary position and the torch made to travel along it, or the torch may be held immovable and the work mounted on a planer table, or comparable device, for carrying it past the torch. Also, the travel of

Fig. 31 (Lower Left)—Typical U and J Joint Designs for Welding

Fig. 32 (Below)—Set-Up for J-Grooving Edge of ½-In. and ¾-In. Plate





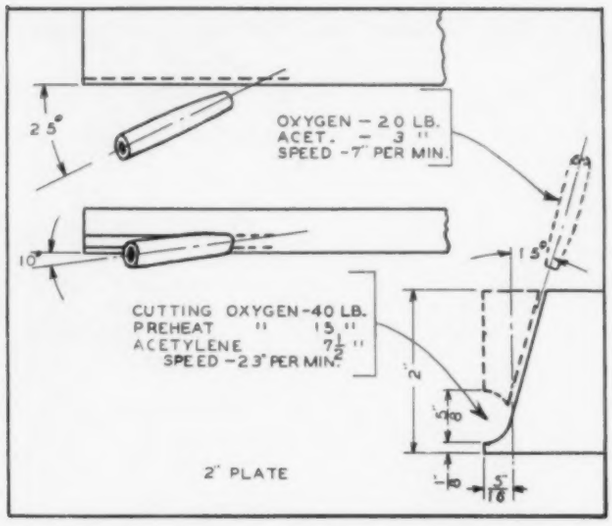


Fig. 33—Procedure for Grooving and Beveling 2-In. Plate

work or torch can be straight-line or rotary. In the former case, the grooves will be straight, while in the latter they will be circular or ring-shaped. Further, in rotating, the cylindrically shaped work can also advance or "feed" axially past the torch in which case helical grooves will result.

U-Grooving of Surfaces

Figure 29 illustrates accuracy of machine flame U-grooving in a plate surface, as seen from the top. Figure 30 shows profiles machine flame U-grooved on plates to give good quality grooves for each tip size used. The dimensional variations of the grooves shown for a given tip were obtained by increasing the oxygen pressure, while maintaining constant the speed of grooving and tip angle settings.

J-Grooving of Edges

At present the principal use for machine flame grooving is for preparing plate edges for welding, where U and J types of joint design are employed. These joints require less weld metal than is necessary with the plain straight beveled joints and, hence, are more economical to weld. They also allow more efficient deposition of initial weld metal beads or layers, by providing more space at bottom to manipulate the electrode. Figure 31 illustrates typical U and J joint designs recommended for metal arc and oxyacetylene welding processes.

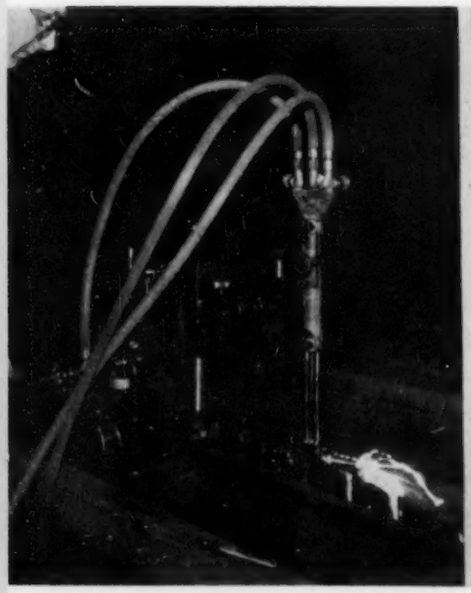
Single U or J joints on lighter plates, $^3/_8$ to $^3/_4$-in. thickness, or double U or J joints on plates $^3/_4$ to $1^1/_4$-in. thickness can be done satisfactorily by machine flame grooving only, without recourse to supplementary beveling. Figure 32 illustrates suggested set-ups for J-grooving $^1/_2$-in. and $^3/_4$-in. plate, using, No. 12 grooving tip. The grooving procedures required for single U or J joints on the thinner plates are essentially duplicated for the double U or J joints on the heavier plates, first on one side and then, after turning the plates, on the other.

Groove base radii are controlled through selection of proper tip size and angle of tip to the plate surface. The desired sidewall angle of bevel of the groove and the required land dimension are controlled by locating the flame grooving tip in a predetermined position in relation to the plate edge (see Fig. 32). In machine flame grooving single U or J joints with land dimension of $^1/_{16}$ in., the plate may be mounted on a suitable quench plate, to prevent the relatively thin land from overheating and oxidizing. Lands of over $^1/_{16}$ in. are maintained satisfactorily without this precaution.

Where the plate edge is irregular or wavy, a floating torch holder is used which automatically follows the hills and valleys and keeps the relative position of the torch to the plate edge constant. Thus, the dimensions and contour of the groove are maintained constant, without attention by the operator.

Grooving Combined with Beveling

As the plate thicknesses become greater, more and more difficulty is encountered in making satisfactory U and J joints by flame grooving alone. By combining flame grooving with beveling, however, U and J joints in heavier plate thicknesses which are entirely suitable for welding can be prepared. Figure 33 indicates diagrammatically one of the procedures followed. As shown in the plan and elevation views of the plate at the top, a root groove is first cut near the bottom of the plate edge. Then, as shown in the end view below, a machine bevel cut, running into the groove, is made, completing the job.



34—Root Machine Flame Grooving a 2-In. Plate

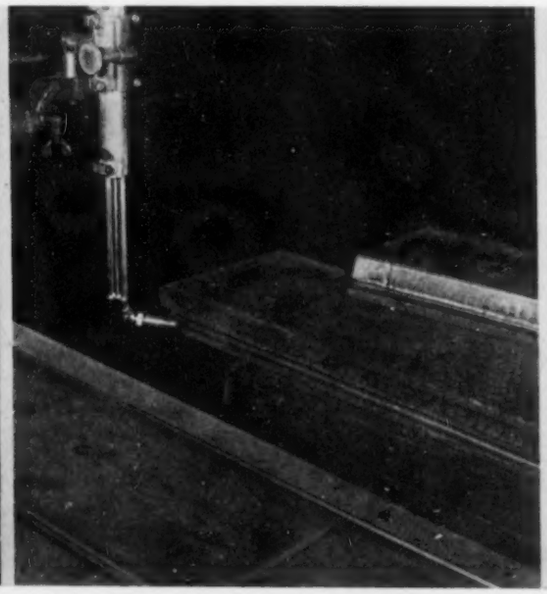


Fig. 35—Completed Root Machine Flame Groove, Showing Tip Position

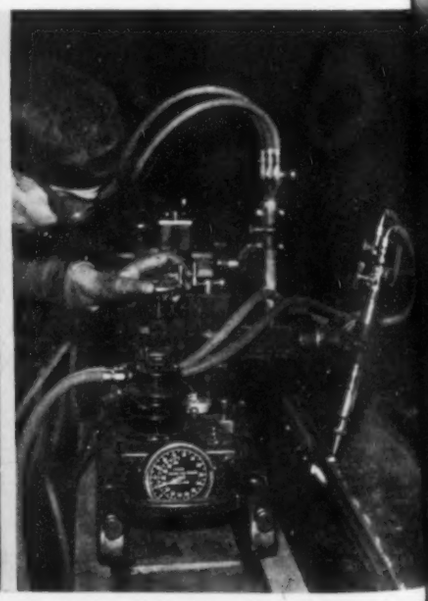


Fig. 36—Bevel Machine Flame Cutting, Down t Groove

Fig. 37—Completed Root Groove and Bevel Cut

Fig. 39—Grooved and Beveled Plate Edge Face, Profile and Partly Welded Joint

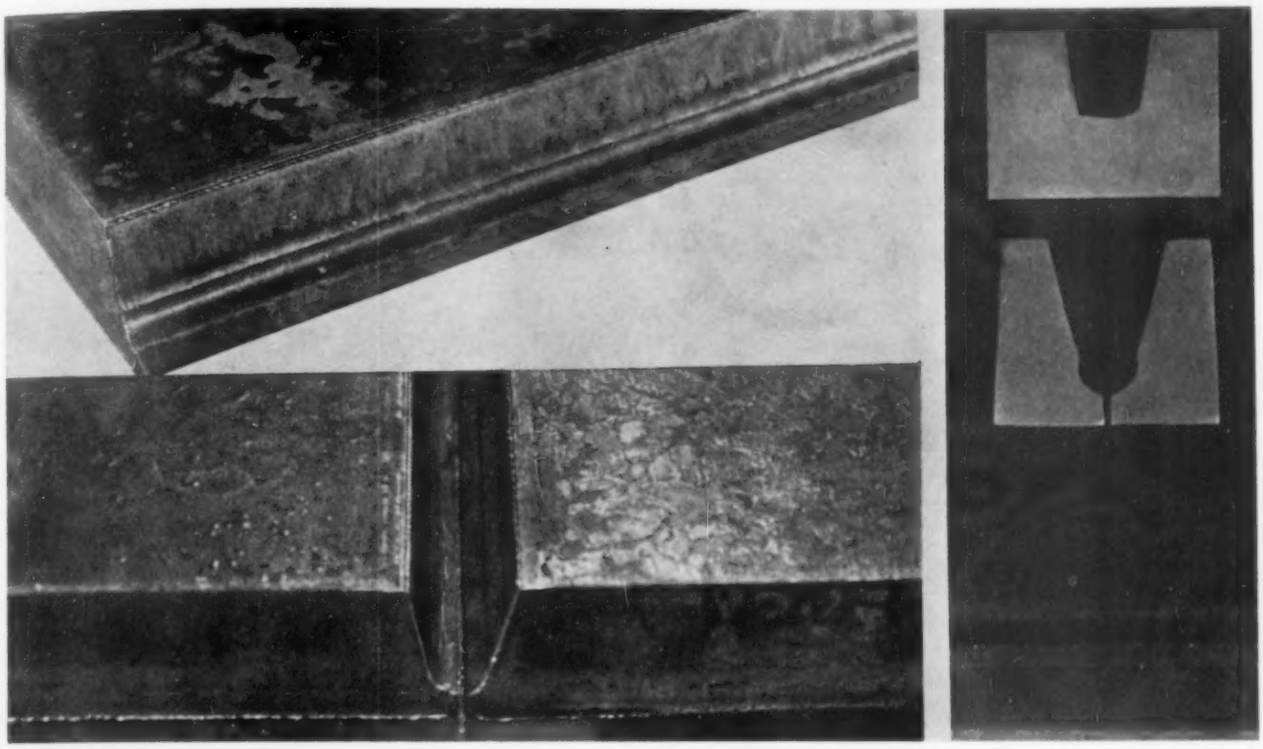


Fig. 38—Two Plates, with Grooved and Beveled Edges, Butted Together for Welding

Photographic illustrations of the procedure are given in Figs. 34 to 37 inclusive. Figure 34 shows the initial root groove of a U groove being made in a 2-in. plate. A cutting machine operating on a straight track, equipped with torch adjusting arm, 90° head torch and No. 12 grooving tip, was employed. Grooving speed was 23 in. per minute. An automatic shut-off for the grooving oxygen was used. Figure 35 shows the completed root groove and the position of the tip relative to the work when making the groove. The groove is smooth with regular contour and the land has even depth.

Figure 36 shows the torch, with No. 2 cutting tip installed, beveling the side of the U groove down into the root groove. Cutting speed was 7 in. per minute. The completed root groove and bevel cut are shown in Fig. 37. Two plates, with completed edges, are butted together in Fig. 38 to form the U groove and are ready for welding.

Figure 39 shows, at the bottom, a face view of completed groove, in the center, a cross section of a single U butt joint profile and, at the top, a partially welded and etched section of the joint. This shows good base penetration and fusion of the side walls. Following the completion of the upper portion of the weld, the bottom side would be removed by flame grooving and back welded, to assure full penetration through the land dimension shown.

Plate Edge Profiles Developed

Figure 40 illustrates profile views of plate edges of various thicknesses prepared by U- and J-grooving alone, as well as by grooving combined with beveling. Joints *A* through *D* represent single U butt joint types, on plate thicknesses of 3, 2, 1 and $^1/_2$ in., respectively. Joint *E* represents a closed root single U groove type. Joint *F* is a double U butt joint on 2-in. plate. Joints *G* and *H* are two forms of single J groove types.

Operating Data

Table 2 gives approximate operating data for flame grooving. Sections *A* and *B* cover progressive manual and machine U-grooving, respectively, in each case of half-round profiles with the width equal to twice the depth and twice the bottom radius. Section *C* covers machine J-grooving of plate edges, of $^1/_2$, $^3/_4$ and 1-in. thickness. Section *D* gives data on combined flame grooving and beveling of 2-in. plate. These data, while quite incomplete, are indicative of the factors involved.

Skilled operators, working on long grooves in materials with clean surfaces, frequently can show higher speeds and lower gas consumptions per linear foot of groove than calculations based on Table 2 would imply. Unskilled operators, working on short grooves in ma-

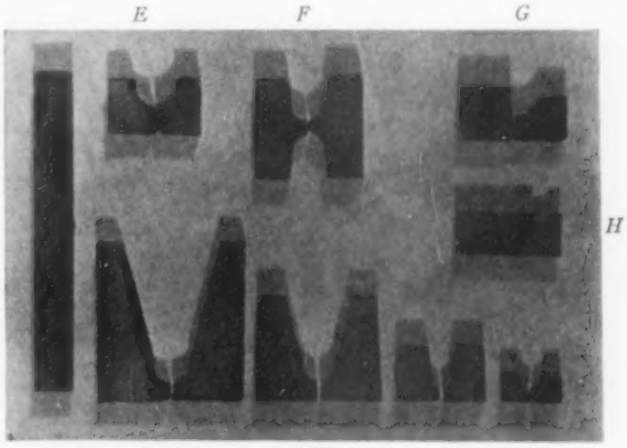


Fig. 40—Various Machine Flame-Grooved Profiles

Table 2—Approximate Operation Data for Flame Grooving

Groove Width, In.	Grooving Tip, No.	Angle[1]	Press. Psi. Oxy.	Press. Psi. Acet.	Speed, In./Min.	Oxygen,[3] Cu. Ft./Hr.	Acetylene, Cu. Ft./Hr.
A—Progressive Manual U-Grooving (Half-Round Profile)							
5/16–3/8	8	25–30°	25	7	12–18	200–215	73– 76
7/16–1/2	10	25–30°	25	7	16–24	275–295	80– 83
9/16–5/8	12	25–30°	25	10	20–32	375–400	100–104
B—Machine U-Grooving (Half-Round Profile)							
5/16–3/8	8	25–30°	30	7	24–30	195–205	40– 45
7/16–1/2	10	25–30°	35	7	28–36	295–310	55– 60
9/16–5/8	12	25–30°	40	8	32–42	450–470	76– 82
C—Machine J-Grooving Plate Edges							
1/2 In. thick[2]	12	17–10°	25	5	13–15	305–320	38– 42
3/4 In. thick[2]	12	17–15°	30	5	10–12	340–355	38– 42
1 In. thick[2]	13	15–10°	30	7	8–12	435–455	46– 52
D—Machine Root-Grooving and Beveling 2-In. Plate							
Groove	12	25–10°	40	7 1/2	22–24	450–470	73– 79
Bevel	2	15°	20	3	6– 8	79– 83	13– 15

[1] For U-grooving, in Sections *A* and *B*, the range of angles given is that which may exist between the axis of the grooving oxygen orifice and the surface of the work, depending on conditions. For J-grooving and root-grooving, in Sections *C* and *D*, the first angle given is that of the tip with the plate edge, while the last angle given is that of the tip with the plate surface.
[2] Thickness of plate.
[3] Total grooving and preheating oxygen.

terials with dirty, rusty or painted surfaces, on the other hand, usually are unable to equal these figures. In setting up Table 2 an attempt has been made to establish average figures, representing ordinary conditions.

Conclusion

Manual flame grooving is, at present, regularly used in hundreds of plants all over the country. Many time- and money-saving applications for both the progressive and spot technique have been discovered. Machine flame grooving, however, has found rather limited field use so far. For one thing, it is in direct competition with flame beveling of plate edges, which latter process appears still to be preferred by the majority of users. Although the U or J joints are somewhat more efficient and economical for welding than the V, or bevel joint, they are also more difficult to prepare accurately by present flame grooving procedures. Further refinements, resulting in greater control and simplicity of the machine flame grooving process, undoubtedly will result in its much wider industrial application also, as it possesses many basic advantages, which need only to be developed.

Flame grooving processes generally have been more or less known for a long time. Until comparatively recently, however, their development was slow, as there was no great industrial demand for them. With the advent of the National Defense Program and the tremendous speed-up in all metal-working industries which it involved, the need for a rapid, economical grooving process soon became extremely urgent. It was indeed most fortunate that flame grooving was able to prove itself equal to the situation and, as a result, it immediately stepped into the breach.

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(*Continued on page 470*)

Modern Assembly Technique Used to Build 45-Foot All-Welded Cupro-Nickel Cabin Cruiser

By Charles G. Miller*

BUILT from the outside toward the inside—from top to bottom—and with the keel laid after the hull had been completed—is *Revere*, the new experimental yacht being built by Revere Copper and Brass Incorporated at the Palmer Scott and Company yards in New Bedford, Mass., from designs of B. T. Dobson, prominent naval architect of that city.

Revere is building this yacht to demonstrate the superiority of light cupro-nickel sheets for pleasure boat construction. The boating industry has long awaited the development of materials and methods which would make possible the use of extremely light metal surfaces for hull plating. A few steel pleasure boats have been built in the past, but because of the necessity of allowing for thinning due to corrosion both on the outside and the inside of the hull, it has been necessary to use plates much heavier than structural requirements indicated. The plates used in *Revere*—both hull and topsides—are 0.080 in. thick. The keel bar is $\frac{1}{2}$ in. thick and varies from 4 in. deep just aft the bow to about 12 in. deep forward the wheel and rudder assembly.

Cupro-nickel, which is a standard alloy composed of 70% copper and 30% nickel, is one of the most corrosion-resistant alloys commercially produced for salt water exposure. So resistant is this alloy that it is widely used by the Navy for tubes in ship condensers where salt water is circulated at high velocity. The strength of the alloy is demonstrated by its use for bullet jackets over a period of many years. The metal is strong, tough and easily worked in the cold condition without rapid work hardening. It also welds readily either by arc, gas or resistance methods.

The original plan for building *Revere*, and the one most

* Revere Copper and Brass Incorporated.

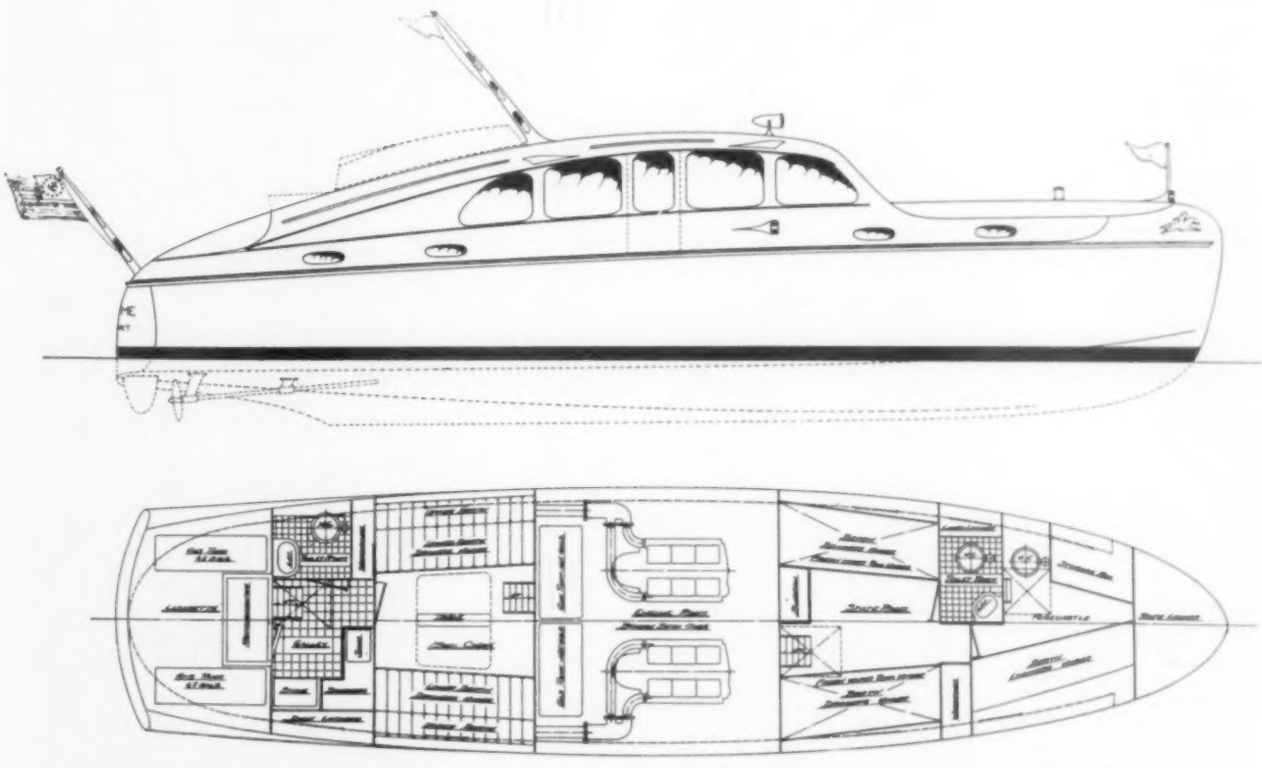


Fig. 1—Profile and Arrangement of Experimental All-Metal Cabin Cruiser Being Constructed at New Bedford, Mass.

Fig. 2—Photograph of Scale Model of the 45-Foot All-Metal Cabin Cruiser "Revere." Note the Streamlining and Modern Design. Headroom in the Cabin Is Seven Feet

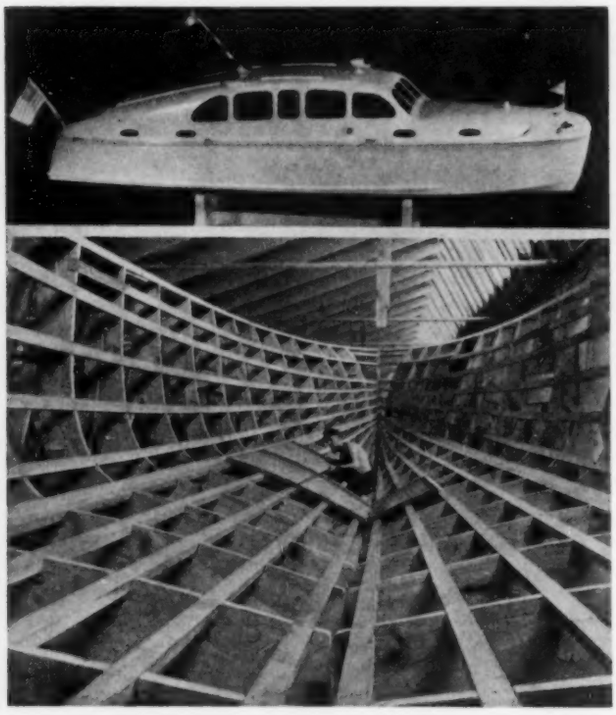


Fig. 3—Second Stage—Properly Shaped and Flanged, the Curved Sections Are Laid Upon a Temporary Supporting Wooden Framework Shaped to the Lines of the Hull. This Framework Is Later Removed

commonly used in previous steel yachts, was based on longitudinal strips running full length fore and aft and butt welding together on the longitudinal seams. Interior framing would then be of the type used by wooden boats of corresponding size and shape. This type of construction usually leads to the extensive use of flat plates and a more or less slabsided, boxy appearance when the boat is completed.

Considerable difficulty is also experienced in keeping distortion due to welding at a minimum. Revere abandoned this method early in the game and developed a flanged cellular construction. These flanged panels are readily formed by a combination of rolling, hammering and breaking of the flanges. Each flanged panel is thus formed to fit the mold at the point of assembly. The joining plates are then spot welded along the flanges just inside the hull surface, arc welded together at the bottom of the flange for the final water seal, and tack welded every four or five inches along the joint on the outside of the hull. This latter welding tends to reduce the possibility of any bellows action which might result in failure by reason of fatigue.

The spot welding was done with a 40-kva. pincer type portable gun welder, and a 15-kva. floor type spot welder. The arc welding was done with a portable arc welder of 150-ampere capacity.

Figure 1 shows the profile and arrangement plan of the yacht. The advanced streamlining was made possible to a large extent by the use of the readily cold worked cupronickel sheet. It should be noted at this point that the arrangements of this boat are unusually complete, providing sleeping accommodations for eight people including a crew of two, and has three toilets and lavatories, tankage for 380 gallons of gasoline, a pair of 316 horsepower engines, and an unusually large battery installation. All of this makes for weight which does not ordinarily go hand in hand with high operating speeds.

A series of hull models were tested in the towing tank at Stevens Institute until a set of lines were developed which would make for speeds in excess of 30 miles per hour with the engines indicated. The models were actually towed to 60 miles per hour and performed well at all speeds although, of course, considerably more power would be required to drive the boat that fast.

Figure 2 shows to better advantage the involved curved surfaces of the hull and superstructure.

Figure 3 shows the first four rolled, hammered and flanged panels being checked for contour in the outside mold. Most wooden boats and, for that matter, the majority of steel boats are built over an inside mold. Since most of the welding of *Revere* is performed on the inside of the boat, it was necessary to use the outside mold.

Fig. 4—Spot Welding Supplementary Angle Stiffeners to Individual Plates

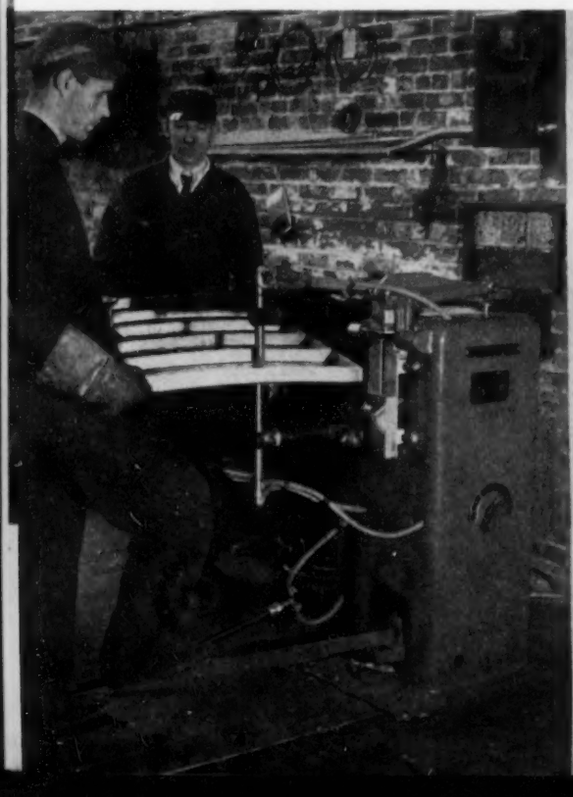
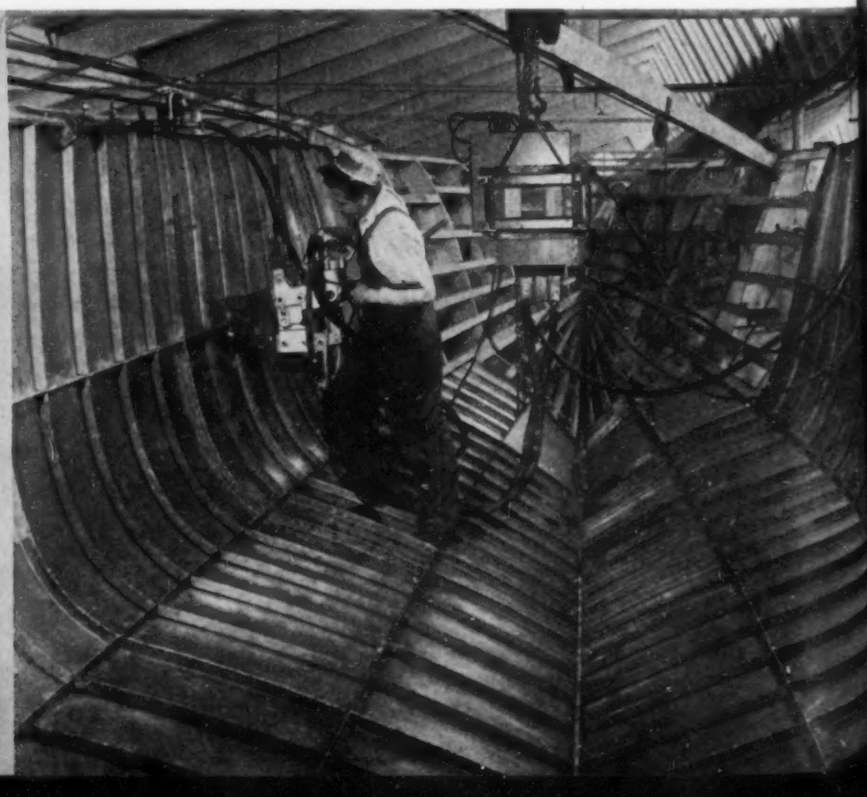


Fig. 5—Portable Spot Welder Joining Individual Panels Together



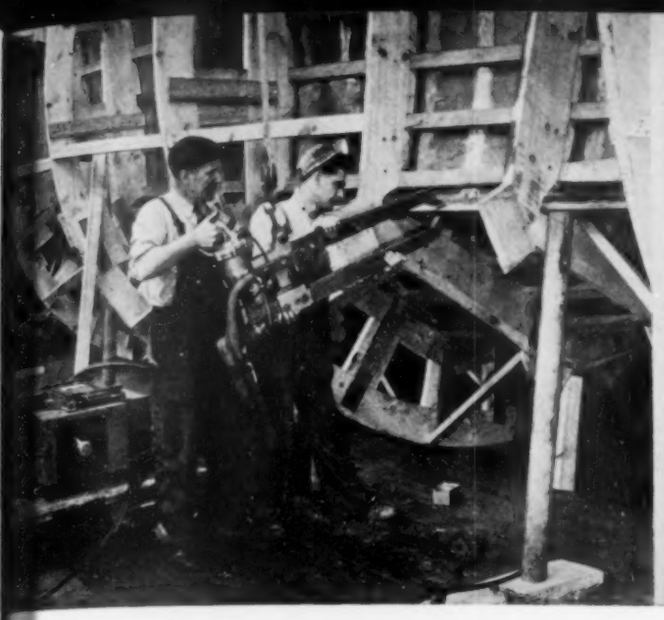


Fig. 8—With the Hull Hove Down, Garboards Are Being Spot Welded to the Keel, Using a Portable Electric Spot Welder with Extra Long Arms

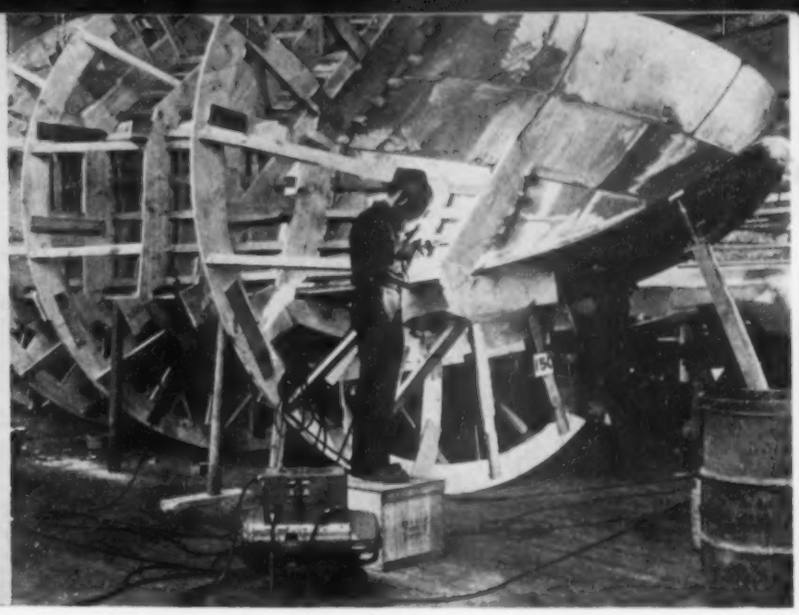


Fig. 9—Later—Arc Welding Garboards to the Keel

Fig. 6—All Hull Sections in Place—Looking Toward Bow of Boat. Flanges of Abutting Metal Sections Have Been Welded Together

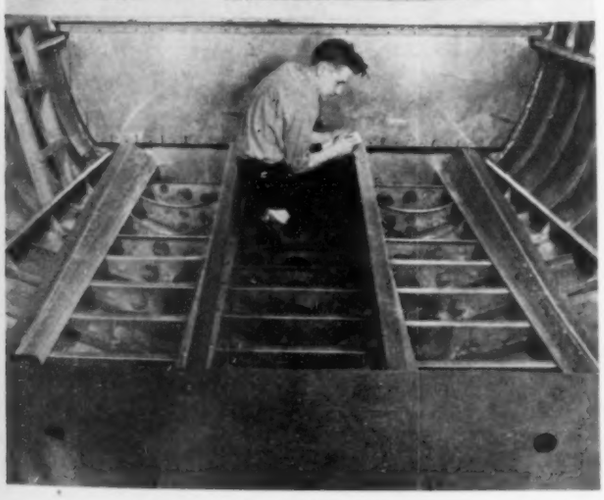


Fig. 7—Section in the Engine Room

Figure 4 shows the spot welding of supplementary angle stiffeners to the individual plates. These stiffeners are also formed from the 0.080-in. material. Their effect is to prevent any tendency of springing when the boat is in motion.

Figure 5 shows the use of the portable spot welder in joining the individual panels together. It should be noted here that the hull and superstructure are entirely welded and there is not one rivet in the assembly. Internal structures such as bulkheads and engine stringers, which are of duraluminum, are largely riveted as a matter of convenience and to permit their disassembly at any time in the future.

Figure 6 shows the completed shell entirely spot and arc welded into one piece. One floor is in position. These floors are spot welded to the flanged joints and also the supplementary stiffeners. It should be noticed here that the keel bar has just been set in place and has not welded to the garboards or lower plates. Because of the difficulty experienced in previous light metal boats as a result of distortion, it was decided in the case of *Revere* to build the flooring system and the engine stringers complete before welding the keel.

Figure 7, which is a section in the engine room, shows how the flooring system and engine stringers are in themselves a welding jig, and, as such, holds the keel in line and minimizes the danger of distortion.

It was mentioned earlier that the outside joints of the hull were tack welded to reduce accordion or bellows effect. The areas between these tack welds will be filled with a standard metal vessel caulking compound and finished off smooth so that the entire exterior surface of the boat will eventually be as smooth as that of an automobile.

Figure 8 shows the spot welding of the garboards to the keel. In this case two spot welds are made, thus joining the 0.080-in.-thick plates to the $^1/_2$-in.-thick keel.

Figure 9 shows the use of an improvised rolling jig which was used to bring certain sections into position for more convenient downhand welding.

Coated cupro-nickel welding rod, $^3/_{32}$ in. diameter, was used for joining the edges of the 0.080-in. plates together on the inside of the boat; $^1/_8$-in rod was used for attaching the garboards to the keel.

Welding Metallurgy

VOLUME II

By O. H. HENRY and G. E. CLAUSSEN

A series of lectures prepared for presentation in a fundamental course of metallurgy and metallography at Polytechnic Institute of Brooklyn under the joint auspices of the Institute and the New York Section of the AMERICAN WELDING SOCIETY. To be published serially in The Welding Journal. The lectures are reproduced in attractive booklet form, copiously illustrated—357 pages—with imitation black leather covers. Volume 1 consists of the first series of 10 lectures given by the New York Section in cooperation with the Polytechnic Institute of Brooklyn last year. Volume 2 includes the series of lectures given this year. The price of the book containing both volumes is $1.50 per copy. Special prices can be arranged for quantity lots of 50 or more.

Part VI—Alloy Steels

Parts II and III describe the welding difficulties that arise from brittleness. The inability of metals under unfavorable conditions of structure and stress to deform or yield more than a slight amount without cracking we found to be associated to a considerable extent, though by no means wholly, with unfavorable chemical composition. With a knowledge of the composition of base metal and weld metal, we can predict the structures that may be expected under different conditions of heating and cooling, and thus we can predict whether the joint is likely to exhibit brittle failure under the conditions of welding and service. The metallurgical principles we use to make the predictions have been mentioned in the preceding parts. The principles are dealt with more thoroughly in the present section with particular emphasis on alloy steels. Besides the class of alloy steels in which brittle behavior forms the major difficulty, a discussion will also be given in Part VII of the corrosion-resisting steels, which owe their value to toughness on an atomic scale (resistance of the atoms of the alloy to be pulled away from each other by corrosive attack).

Composition of Base Metal

Hard Cracks

The hard, martensitic zone close to the weld forms when the cooling rate exceeds the critical cooling rate. There has been insufficient time during cooling for the austenite to transform completely to ferrite and carbide; instead martensite has been the product of transformation. The term "hardenability" is used to express the relative rate of cooling that is required to prevent transformation of austenite to anything else than martensite.

There are several ways in which hardenability is expressed numerically. The time T in Fig. 42 might be used, did we not know from Fig. 9 that for our heat-affected zone which is cooling through all temperatures, the time T is not the only decisive factor for preventing transformation of austenite. The portions of the S-curve (for explanation of S-curve see Part IX of Vol. I and Fig. 9 of Part II of Vol. II) at higher temperatures than the nose also influence the transformation. Another measure of hardenability is the depth of the martensite (hardened zone) in a round bar of the steel under investigation that has been water quenched under standardized conditions. The instantaneous cooling rates of a bar of a given diameter during quenching are known to decrease as the center is approached. The cooling rate—a measure of hardenability—corresponding to the boundary of the martensitic zone is expressed by

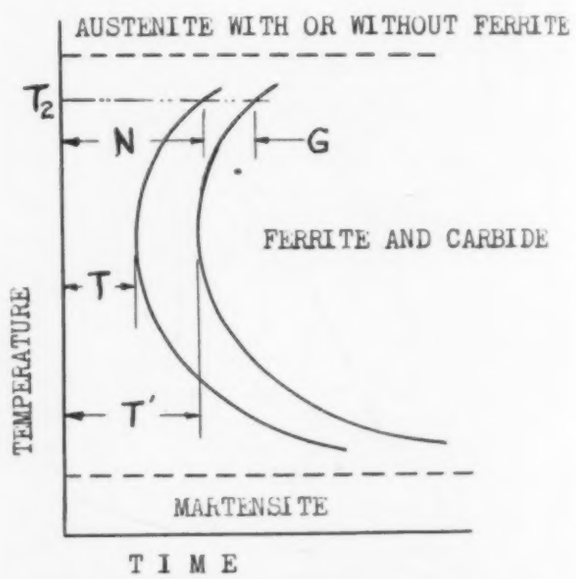


Fig. 42—The S-Curve as a Basis for Estimating Hardenability

T = Least time during which austenite is stable before its transformation sets in (possibly a measure of hardenability)
= Least time during which austenite is transformed completely to ferrite and carbide
N (nucleation stage) = Time during which no nuclei of ferrite or carbide appear in the austenite at temperature T_2. The first nucleus forms at the expiration of time N. The curves show that the time N is different for each temperature at which the specimen is held
G (growth stage) = Time during which the nuclei grow from the austenite. At the expiration of time $N + G$ no austenite remains

the depth of the martensitic zone, which thus becomes a measure of hardenability. Hence arises the expression "deep hardening steel." A steel which hardens deeply forms a thick or deep martensite zone when quenched in water from above the critical range, whereas a thin zone is secured when a "shallow hardening" steel of the same diameter is quenched under the same conditions. The deep hardening steel has a slower critical cooling rate than the shallow hardening steel. Consequently the austenite of the shallow hardening steel will transform to ferrite and carbide at cooling rates at which the austenite of the deep hardening steel will refuse to transform to anything else than martensite.

Hardenability does not mean that the steel can harden to some arbitrary figure, such as 600 Brinell. It signifies rather that the steel can become martensite, the hardness of which depends almost entirely on the carbon content, Fig. 11. A deep hardening steel has greater, higher or simply deeper hardenability than a shallow hardening steel, which has the higher critical cooling rate. The deeper hardening steel will suffer from hard heat-affected zones under less severe conditions of welding than the shallow hardening steel. For example, the need for preheating increases as the depth of hardening of the steel increases.

The degree of hardenability of a steel depends upon the transformation of the austenite of which the steel is composed above the critical range and for some time during rapid cooling. There are two stages in the transformation: nucleation and growth. During the first stage no austenite transforms, but it is becoming ripe for buds; that is, the austenite is becoming ready for the appearance of nuclei. Perhaps nuclei form at once but immediately re-dissolve, being too small to live.

We know that nuclei form more quickly at any discontinuity in the lattice of the austenite, than in the undistorted lattice itself. Discontinuities are grain boundaries and particles of any material that is not austenite, such as slag, oxides and carbides.

We also know that the addition of elements to austenite generally delays the appearance of nuclei of ferrite or carbide during cooling. Two reasons are offered: (1) the atoms of added elements, which have no prior knowledge about austenite transformation, replace iron atoms to whom austenite transformation is instinct. With unresponsive strangers occupying the place of neighbors, the remaining iron atoms require more time to find other iron atoms with which to undergo mass crystal change to ferrite or carbide. (2) Alloying elements strengthen the austenite and make mass crystal movement more difficult than in unalloyed iron. Neither reason is satisfactory because one alloying element at least, cobalt, hastens the transformation of austenite.

Nucleation then is retarded by: (1) addition of alloying elements; (2) increase in grain size, which decreases the amount of grain boundaries; (3) inclusions, particularly tiny ones. It would simplify matters if we could express numerically the influence of each of these factors upon hardenability. Unfortunately, numerical estimates of a foolproof sort cannot be made at present. We can state that from the welding viewpoint the composition of the base metal is more important than the grain size and inclusion factors. The heat-affected zone always is relatively coarse grained in any type of weld, and the presence of inclusions influences the hard zone only if steels of otherwise the same composition are compared.

The main alloying element increasing the hardenability of iron is carbon. Thus, the carbon content governs not only the maximum hardness that can be attained by a steel, but, if to a less extent, the hardenability as well. For example, the critical cooling rate may fall from 1400° C. per sec. for iron containing 0.2% C to 700° C. per sec. with 0.6% C. The alloying elements are less influential than carbon. Molybdenum and vanadium seem to exert most effect in lowering the critical cooling rate, while chromium, manganese and nickel exert progressively decreasing effect. The other elements in steel have comparatively little effect on hardenability in the customary percentages.

Alloying elements may also affect hardenability by forming inclusions. Aluminum in steel may form aluminum oxide (alumina), which hastens the transformation of austenite. Molybdenum and vanadium may form carbides which, by removing the alloying elements from solid solution in the austenite as well as by acting as inclusions, also hasten austenite transformation. It is possible, for example, that molybdenum carbide is not dissolved during the brief heating period of welding and may hasten austenite transformation during cooling. Welding experience with 0.20% C, ½% Mo steel does not support the supposition, for hard zones are not easy to avoid in these steels. Experiment has shown that in plain carbon steel with 0.2% C all carbides have gone into solution after 8 seconds at 800° C. However, by adding titanium to a deep hardening steel, we cause a large proportion of the carbon to form titanium carbide, which refuses to dissolve to any extent in austenite during welding. During cooling the austenite behaves as a relatively low carbon austenite, containing inclusions; its transformation is rapid, it is shallow hardening and severe cooling conditions can be imposed without the formation of hard zones. The carbide has been "stabilized" by the titanium, whence the expression "carbide stabilization" for the method of preventing hard zones. It is doubtful whether the inclusions are effective in preventing grain growth in the heat-affected zone. Inclusions cannot be relied upon to restrain grain growth above 1000° C. Since the heat-affected zone closest to the weld, which is the region of hard zones, reaches 1400° C., we cannot expect inclusions to promote shallow hardening and absence of hard zones, by maintaining fine grain size in the heat-affected zone.

The second stage in the process of transformation of austenite remains to be considered, namely: growth. Once the nuclei of ferrite and carbide form in the austenite, they grow, as shown in Part VIII of Vol. I. The time occupied in the growth of the ferrite and carbide, which is the same as the time required, *G* in Fig. 42, for the austenite to disappear, is important for the formation of hard zones. Austenite may start to transform rapidly, but if it requires a long time to complete its transformation, a large proportion is likely to persist to the temperature at which the remaining austenite changes to martensite. Despite rapid nucleation, the austenite forms hard zones consisting mainly of martensite under relatively gentle cooling conditions. We see that the rate of growth of the nuclei is as important as the time elapsed before nuclei appear. The rate at which a nucleus grows, expressed as inches of radius per second, is slow at first, because its area of contact with austenite is small, that is, the grain boundary area. As the nucleus becomes larger, its rate of growth increases, later to decrease as the amount of remaining austenite becomes insignificant. The alloying elements tend to concentrate in the remaining austenite, which, as well as its small surface area, accounts for the decrease in rate of growth of the nuclei in the final stages of transformation.

The same factors tending to retard nucleation of austenite during cooling retard the growth of the ferrite and carbide nuclei to which the austenite transforms. So

strong is the effect of large quantities, say 10%, of some alloying elements (manganese and nickel) in preventing the growth of ferrite nuclei that the austenite cannot be transformed at any temperature. These are the high-alloy steels which remain partly or wholly austenitic at all temperatures.

As a result the chief factor that increases hardenability is the composition of the steel. And the chief element in the composition is the carbon content. Consistently to avoid hard zones with possible hard cracks under severe welding conditions, the carbon content must be restricted to less than 0.15–0.20%. Instead of increasing the strength of steel for bridges, pressure vessels and similar welded objects by increasing the carbon content, it often is preferable to maintain low carbon content and add alloying elements. If alloying elements must be added to confer a property that increase in carbon cannot confer, for example, high creep value at 1000° F. conferred by adding molybdenum, it is likewise necessary to maintain low carbon content. If it is inconvenient to use alloying elements, or if high carbon content is mandatory, special precautions must be taken during welding, such as preheating, to prevent hard zones and hard cracks. The classification of low-alloy steels for welding recommended by the Committee on Low-Alloy Steels of the Welding Research Committee (see Part X of Vol. I) is based to a considerable extent on carbon content and hardening.

Hot Cracks

The hot cracks that occur in base metal are rare and are confined to a few applications for which correct welding procedures to avoid cracks are known. The best example of hot cracks in base metal is found in the welding of chromium-molybdenum steel (0.30% C, 1.0% Cr, 0.2% Mo) aircraft sheet and tubing. The cracks are intergranular and appear when the carbon content is increased from 0.15 to 0.30%. Since the cracks are cured by reducing the heat input in welding, it is surmised that they are related to inability of the hot steel to deform near the melting range (see Fig 20 (*a*)). Although it is possible, therefore, to cure the cracks by changing the composition of the steel, the preferable solution is to make simple changes in welding procedure to reduce shrinkage and prevent widespread overheating of base metal. Hot cracks also may occur in base metal with exceptionally high sulphur content and inadequate manganese. Cracks under these conditions may be attributed to "hot shortness," but the conditions are rarely encountered.

Hot cracks in weld metal also respond to changes in composition of base metal. Base metal may influence the cracking by affecting the rigidity of the joint, but the principal effect is exerted through pick-up. The weld metal deposited by covered electrodes mixes with base metal. As a matter of fact in the first run of a fillet weld 40 to 60% of the melted metal is base metal melted by the arc. If the carbon and alloy content of base metal is high, the weld metal will have correspondingly high contents, which, under some conditions not yet understood precisely, lead to hot cracks. Hot cracks with bare electrodes are rare because, for one thing, the oxidation in the unprotected weld puddle is so severe that carbon and some alloying elements from base metal are oxidized completely.

Laminations

Ordinary chemical analysis of a steel yields no information about the presence of large inclusions or laminations (see Part VII of Vol. I). They are composed principally of oxides, sulphides and silicates of iron and manganese, arise from incomplete separation of slag from metal in the ingot and are detected by the homogeneity test. The test may consist of examining the surface of a bend or tensile fracture, or of an oxygen cut surface for the laminations, which are revealed unmistakably in the fracture or on the oxygen cut surface. The homogeneity test is designed to indicate only large inclusions that may extend continuously several inches in the plate. It is similar to the inclusion rating test that must be passed by many forging and automotive steels. The inclusion rating of a steel is an estimate of the size and distribution of the inclusions in a steel on a microscopic scale. Laminations in boiler and structural plate are visible to the unaided eye.

Laminations are serious for several reasons. In the first place, they reduce the transverse strength of the steel; that is, the strength in the direction perpendicular to the surface. In the fillet weld in the laminated plate of Fig. 43 (*c*) fracture, instead of passing through the throat of the fillet as it should, opened a crack along a lamination. Under some conditions laminations act as a safety valve in interrupting the progress of a crack, but too frequently they do no more than weaken the steel

Fig. 43

(*a*) As resistance welded, showing upset laminations
(*b*) After machining, showing cracks opening at the upset laminations. Traced from photograph by Torgler)
(*c*) Path of rupture following a lamination
(*d*) Cracks in weld metal starting at a lamination opened by welding

seriously. Another instance of undesirable effects due to laminations is illustrated by the resistance butt or flash weld in Fig. 43 (*a*). The inclusions as well as the metal are upset by push-up, and appear on the surface after the flash is trimmed, Fig. 43 (*b*).

The most dangerous difficulty from the welding standpoint is illustrated in Fig. 43 (*d*). The lamination has not been sealed over by the weld puddle, as almost always happens with smaller inclusions or with larger inclusions that have favorable composition. Instead of being sealed over, the lamination has been affected by the heat of welding, has opened a crack into base metal, and by contaminating the weld metal in its vicinity, has caused it to crack. The dangerous cracks can be avoided only by ascertaining that the plate is free from laminations to start with. The plates rolled from the top of an ingot are most likely to be laminated, because much of the slag that is present is trapped in the last metal to solidify.

Cracks under Stress

If failure occurs in service and there is considerable deformation around the fracture, it is a sign that the metal was satisfactory for the purpose, but that the part was inadequately designed. When the fracture exhibits no deformation there are two deductions that may be made. First, multi-axial tensile stress may have been applied at the point of fracture. Multi-axial tensile stresses inherent in the design of the part or created by

notches should be prevented so far as possible by selection of a tough base metal. A tough steel is characterized by high notch impact value, which is particularly important for structures to operate at sub-zero temperatures. High notch impact value being associated with fine grain size in the low-carbon and low-alloy steels that are used, it has been found that weld metal and heat-affected zone, which are finer grained than unaffected base metal, are not the determining factors for the toughness of the welded structure as a whole. Should it happen that unrefined weld metal or heat-affected base metal are present, then it is the notch impact value of the coarse zones that determine the toughness of the structure and its tendency toward brittle failure.

The second deduction that may be made from a brittle failure is that a hard, heat-affected zone was present. The factors in the composition, particularly the carbon content, that govern the formation of hard zones have been discussed in the section on "Hard Cracks." Hard zones may be prevented in steel of any carbon content by appropriate preheating and stress relief heat treatment.

Steels Suitable for Welding

In concluding the discussion on the composition of base metal we will exemplify general principles by listing the steels that are acknowledged to be suitable for welding by major specification organizations. Some of the steels were discussed in Parts II and X of Vol. I. By "suitable for welding" is meant that the steel can be welded satisfactorily by well known techniques in the forms and for the applications that the specification for the steel describes. It is not implied that other steels not mentioned in the specifications may not be equally suitable. As a matter of fact, there are hundreds of steels, if not all steels, that are suitable for welding if due consideration is paid to welding technique and to the properties desired in the welding structures. Only some of the steels standardized by the A. W. S., A. S. T. M. and Boiler Code Committee will be discussed in the following paragraphs.

The compositions that are specified refer either to the analysis of the steel in the ladle before teeming into ingots, or to the analysis of the steel in the form (plate, beam, etc.) in which it is to be welded. Analyses of the latter type are called "check analyses," samples for which are taken at any point midway between outside and center of the section by drilling parallel to the rolled surface. In thin material the sample may be taken across the entire cross section. The check analysis may not be the same as the ladle analysis, because for one thing the elements segregate in the ingot. Consequently, wider limits sometimes are allowed in the check analysis than in the ladle analysis.

The permissible limits within which the elements may vary are not necessarily the limits within which they will vary in practice. For example, the carbon content of High Tensile Strength Carbon-Silicon Steel Plates for Boilers and Other Pressure Vessels (A. S. T. M. Specification A212-39) may be anything up to 0.31% for Grade B steel. Obviously the carbon content never would be so low as 0.05% although it would be permissible, because a tensile strength of 70,000 lb./in.^{2} never could be attained in thick hot-rolled plates of that carbon content. The permissible limits of strength likewise may not necessarily represent the limits within which they will vary in practice. Again as an example, the minimum tensile strength of Corrosion-Resisting Chromium-Nickel Steel Sheet, Strip, and Plate is given by A. S. T. M. Specification A167-39 as 75,000 lb./in.^{2} Yet Grade 10 steel in the specification (25 Cr–20 Ni) would never be expected to fall below about 90,000 lb./in.^{2} in practice. The minimum tensile strength is specified simply as a safeguard against metal that is obviously defective mechanically while meeting the more important specified composition, which controls the corrosion resistance. Often an upper as well as a lower limit is placed on tensile strength to prevent the use of metal of excessively high tensile strength, which may imply poor service characteristics despite satisfactory ductility in the tensile test of a machined bar.

The selection of limits within which the composition and properties of a welding steel must fall is governed primarily by the requirements of service and fabrication; nevertheless, so far as possible the steel manufacturer is relieved of all unnecessary burden. One of the greatest burdens placed upon steel manufacturers in specifications for welding steels is low carbon content. Production of steels with low carbon content involves long refining times and high temperatures, both of which reduce the life of the furnace linings and increase the difficulty of eliminating slag inclusions. Besides composition and tensile strength, the yield point and ductility of the steel in the tensile test is specified for the welding steels and they must pass a bend test and a homogeneity test to demonstrate satisfactory forming qualities and absence of laminations. It is generally difficult to produce a rimming steel that will pass the homogeneity test consistently; no alloy steel will be manufactured by the rimming process. Nevertheless, plain-carbon steel plates and structural products containing 0.15–0.25% C often are made of semi-killed steel, which is made by a process intermediate between rimming (no silicon) and killing with silicon. Low-carbon steel sheets (0.05–0.15 % C) generally are made of rimming steel.

Dealing first with steels for welded bridges and buildings, we find that the AMERICAN WELDING SOCIETY limits the carbon content to 0.25%, as explained in Part II of Vol. I.

Another important class of steels is that suitable for boilers and other pressure vessels. Welding is used almost exclusively for joints in these vessels for steam power, refinery and chemical purposes having wall thicknesses up to 6 inches or more. The following A. S. T. M. and Boiler Code Specifications apply to these steels.

Several items may be commented upon. Stricter requirements are placed upon firebox-quality than upon flange-quality plate. The maximum permissible carbon content is higher for thick plates than for thin, although we know that hard zones are favored by increase in *both* thickness and carbon content. Ideally we should wish the carbon content to be lower in the thicker plates than in the thin to avoid hard zones. However, to meet strength requirements the steel manufacturer must be permitted to supply higher carbon content in the thicker plate which cannot be rolled to so great an extent as thin plates. The higher phosphorus content permitted in steels made in acid (sand lined) furnaces than in basic reflects the inability of the acid

A 70–39 Carbon-Steel Plates for Stationary Boilers and Other Pressure Vessels (Boiler Code Specification No. S-1)

	Flange	Firebox
Carbon, max. per cent		
3/4 in. and under	..	0.25
Over 3/4 in. to 4 in.	..	0.30
Mn, max per cent	0.80	0.80
P, max. per cent acid	0.05	0.04
P, max. per cent basic	0.04	0.035
S, max. per cent	0.05	0.04

process to remove phosphorus from the charge, which must therefore be of a lower phosphorus content (signifying better quality in general) than in the basic process. This specification and nearly all others for these steels also require that plates over 2 inches thick be uniformly heat treated (liquid quenching not permitted) to refine the grain size before fabrication and welding. The heat treatment may involve normalizing which improves particularly the ability of thick plates to be formed to shape, and also improves the ability of the steel after welding to resist propagation of a crack under stress.

In contrast with A 70, a silicon content of 0.15–0.30% is specified in A 201 in order to limit the carbon content

A 201–39 Carbon-Silicon Steel Plates of Ordinary Tensile Ranges for Fusion-Welded Boilers and Other Pressure Vessels (Boiler Code Specification No. S-42)

	Grade A	Grade B
Carbon, max. per cent		
1 in. and under	0.20	0.24
Over 1 in. to 2 in.	0.24	0.27
Over 2 in. to 4 in.	0.27	0.30
Over 4 in. to 6 in.	0.31	0.35
Mn, max. per cent	0.80	0.80
Si, per cent	0.15–0.30	0.15–0.30
Tensile strength, lb./in.²	55,000–65,000	60,000–70,000

to the lowest practicable amount consistent with the specified thickness and tensile strength. The permissible sulphur and phosphorus contents of flange and firebox qualities are so closely the same in A 201 and other specifications as in A 70 that they are not repeated.

A 212–39 High Tensile Strength Carbon-Silicon Steel Plates for Boilers and Other Pressure Vessels

	Grade A	Grade B
Carbon, max. per cent		
1 in. and less	0.28	0.31
Over 1 in. to 2 in.	0.31	0.33
Over 2 in. to 4½ in.	0.33	0.35
Mn, max. per cent	0.90	0.90
Si, per cent	0.15–0.30	0.15–0.30
Tensile strength, lb./in.²	65,000–77,000	70,000–82,000
Yield point, lb./in.²	0.5 T.S.	0.5 T.S.

The higher strength in A 212 compared with A 201 is secured by higher carbon and manganese contents. Four types of alloy steels used for welded pressure vessels are listed below.

A 204–39 Molybdenum-Steel Plates for Boilers and Other Pressure Vessels (Suitable for Welding) (Boiler Code Specification No. S-44)

	Grade A	Grade B	Grade C
Carbon, max. per cent			
1 in. and less	0.18	0.20	0.23
Over 1 in. to 2 in.	0.21	0.23	0.26
Over 2 in. to 4 in.	0.23	0.25	0.28
Over 4 in. to 6 in.	0.25	0.27	..
Mn, per cent	0.50–0.90	0.50–0.90	0.50–0.90
Si, per cent	0.15–0.30	0.15–0.30	0.15–0.30
Mo, per cent	0.40–0.60	0.40–0.60	0.40–0.60
Tensile strength, lb./in.²	65–77,000	70–82,000	75–87,000
Yield point	0.55 T.S.	0.55 T.S.	0.55 T.S.

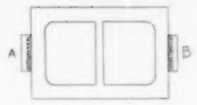


Fig. 44—Frame with Attachments Welded at *A* and *B*

A 225–39 T Manganese-Vanadium Steel Plates for Boilers and Other Pressure Vessels (Suitable for Welding)

	Grade A	Grade B
Carbon, max. per cent	0.18	0.20
Mn, max. per cent	1.45	1.45
Si, per cent	0.15–0.30	0.15–0.30
V, per cent	0.08–0.14	0.08–0.14
Tensile strength, lb./in.²	70,000–82,000	75,000–87,000
Yield point	0.55 T.S.	0.55 T.S.

It is specified in A 206 that the steel-melting practice must produce a structural grain size corresponding to A. S. T. M. grain size 3 to 6 after the following heat treatment. Heat to 1700° F., hold 1 hr. per inch of wall, but in no

A 202–39 Cr-Mn-Si Alloy-Steel Plates for Boilers and Other Pressure Vessels Up to 2 Inches Thick (Not Stated to Be Suitable for Welding) (Boiler Code Specification No. S-28)

	Grade A	Grade B
Carbon, max. per cent	0.17	0.25
Mn, per cent	1.05–1.40	1.05–1.40
Si, per cent	0.60–0.90	0.60–0.90
Cr, per cent	0.30–0.60	0.30–0.60
Tensile strength, lb./in.²	75,000–90,000	85,000–100,000
Yield point	0.6 T.S.	0.55 T.S.

A 203–39 Low-Carbon Nickel Steel Plates for Boilers and Pressure Vessels (Not Stated to Be Suitable for Welding) (Boiler Code Specification No. S-43)

C, per cent	0.17 max. or 0.25 max.
Ni, per cent	2.0–2.75
Si, per cent	0.15–0.30
Mn, per cent	0.80 max.

The tensile limits are 65,000–77,000 lb./in.² for the grade with 0.17% C max.

instance less than 1 hr., cool in the furnace at a rate not over 50° F. per hr. until below 1000° F. The term "structural grain size" refers to the predominant grain

A 206–39 T Seamless Carbon-Molybdenum Alloy-Steel Pipe for Service at Temperatures from 750 to 1000° F. (Suitable for Fusion Welding) (Boiler Code Specification No. S-45)

0.10–0.20 per cent C
0.30–0.60 per cent Mn
0.10–0.50 per cent Si
0.45–0.65 per cent Mo

ferrite grains, Widmannstätten areas or pearlite patches. The grain size specification is made in the interests of high creep value. The change in ferrite grain size in the vicinity of a welded joint extends over a relatively short length of the pipe.

These specifications for forge welding are similar to A 89–39 (Boiler Code Specification No. S-2) for Low-

Tensile Strength Carbon Steel Plates of Flange and Firebox Qualities, suitable for water gas pressure welding without fluxes. In the interests of good forge welding strict limitations are placed upon the silicon, nickel

A 78–39 Steel Plates of Structural Quality for Forge Welding

Carbon, max. per cent	0.15–0.22 depending on grade and thickness
Mn, per cent	0.35–0.60
P, per cent	0.06
S, per cent	0.055
Ni, per cent	0.05
Cr, per cent	0.05
Si, per cent	0.05

and chromium contents. Nevertheless, nickel steels gave no trouble in forge welding in recent production tests.

Several tentative specifications deal with steel castings suitable for fusion welding. A 215–39 T for Carbon-Steel Castings Suitable for Fusion Welding for Miscellaneous Purposes lists eight grades with 0.25% C, max. or 0.35% C, max., 0.50% Si, max., 0.60% or 0.75% Mn, max., 0.06% S, max., 0.05% P, max. The minimum tensile strengths are 60,000 lb./in.^{2} for the lower carbon grades and 70,000 lb./in.^{2} for the higher carbon. Before they are welded all castings must be normalized or full annealed. Use of liquid or air blast for cooling is not permitted for these heat treatments. The object of the heat treatment is to relieve shrinkage stresses due to casting and to refine the cast structure of the steel. In this way welding is performed on the steel in its strongest and most ductile condition.

Often, without adequate reason, steel castings are said to be more difficult to weld than wrought steel. It is true that the carbon content of steel castings generally is rather high from the welding view-point, 0.20% or higher, combined with higher manganese and silicon contents than will be found in wrought plain-carbon steel. The high manganese and silicon contents of steel castings are necessary for satisfactory deoxidation. Substitution of alloying elements for carbon is said to decrease cracking difficulties, as in low-alloy wrought steel (see A. S. T. M. A 217–39 T). The welder must allow also for the complicated shape of many steel castings. If, in the cast steel frame in Fig. 44, parts are welded simultaneously at *A* and *B*, the expansion of the end members may seriously strain the middle strut or may start cracks at the sharp corners. Had the casting been of gray cast iron instead of cast steel, any welding at *A* and *B* would be expected to crack the middle strut. Gray cast iron, which contains 3–3½% carbon, is entirely different from cast steel. The former exhibits practically zero elongation at fracture in the tensile test, whereas the ductility of cast steel compares favorably with that of wrought steel. Since cast steel is subject on a large scale to the shrinkage cavities, porosity and hot cracks that sometimes afflict welds, repairs to steel castings should not be attempted until chipping has reached perfectly sound metal. Cracks may spread during welding from the slightest defect that is not removed beforehand.

The A. S. T. M. Specification A 216–39 T for Carbon-Steel Castings Suitable for Fusion Welding for Service at Temperatures up to 850° F. lists two grades each having 0.70% Mn, max., 0.50% Si, max. Grade WCA is limited to 0.25% C, max. (minimum tensile strength equals 60,000 lb./in.^{2}), while Grade B is limited to 0.35% C, max. (minimum tensile strength equals 70,000 lb./in.^{2}). In addition, the specification takes into account the fact that unspecified alloying elements may get into the cast steel through the scrap or by worthy intent to obtain superlative properties. In order that these additions may not become troublesome in welding, they are restricted to 0.50% Cu, max., 0.50% Ni, max., 0.25% Cr, max., 0.25% Mo plus W, the total content of these elements not to exceed 1.0%.

A. S. T. M. A 217–39 T Alloy Steel Castings Suitable for Fusion Welding for Service at Temperatures from 750 to 1150° F.

	WC1	WC2	WC4
C	0.30 max.*	0.25 max.*	0.20–0.30
Mn	0.70 max.*	0.70 max.*	0.40–0.70
Si	0.50 max.	0.50 max.	0.25–0.55
Mo	0.40–0.60	0.40–0.60	0.30–0.45
Ni			0.75–0.05
Cr			0.40–0.70

* For each reduction of 0.01% below maximum carbon, an increase of 0.04% Mn above maximum is permitted up to 1.10% max. Mn.

Before they are welded, these castings must be heat treated to place them in the best condition to resist welding stresses. Four heat treatments may be used:

(*a*) Full anneal (heat above critical and cool in furnace).
(*b*) Normalize then full anneal.
(*c*) Normalize then stress relief heat treatment (also called "drawing") which consists in this specification of heating 1½ hr. per inch or less of section at 1100–1250° F. and cooling in furnace or still air.
(*d*) Full anneal, then normalize, then stress relief heat treatment. Treatment (*a*) is adequate for simple shapes, whereas (*d*) is appropriate for complicated castings of the higher carbon contents.

In concluding the discussion of the effect of composition of base metal on welding difficulties, we recall that there are other classes of materials than those mentioned that are suitable for welding. Wrought iron is a noteworthy example. Containing 0.08% C, 0.02% Mn, 0.01% S, 0.06% P, 0.15% Si, wrought iron is free from hardening tendencies. However, it may contain 1.2–2.9% by weight slag, which at first sight might be construed as providing difficulties with laminations. No difficulty is experienced in practice, perhaps because the slag contains no constituents that yield gases or FeS during welding, for it is the sulphur content of laminations in the segregated regions of defective steel that seems to cause the cracking during welding.

An outstanding example of a material that requires the greatest care in welding is gray cast iron, of which there are many grades ranging from 25,000 to over 60,000 lb./in.^{2} tensile strength. None has appreciable ductility and all are likely to crack during welding unless they are preheated. Adding to its weakness and lack of ductility is the propensity of cast iron to form zones as hard and brittle as glass close to the weld metal. In these zones the molten iron has dissolved perhaps 3% carbon which transforms to iron carbide instead of graphite during rapid cooling after welding. Like high-carbon steel, the heat-affected zone of cast iron tends to be martensitic. The difficulties with hard zones may be avoided

by adopting bronze welding instead of fusion welding, but difficulties with cracks due to stresses arising from differences in temperature throughout the casting are inherent in any process.

Composition of Weld Metal

It should be realized at the outset that there are no standard specifications for composition of weld metal comparable with the large number of standard compositions of wrought and cast steels. A major consideration in the selection of an electrode is the position in which it is to be deposited, which is governed by the type of coating, not by the composition of the weld metal. Furthermore, the composition of the metal deposited by a given rod will depend on the composition of base metal, and on the proportion of base metal that is melted into the deposit. Despite these facts and the fact that filler metal usually is classified according to its tensile strength, the composition of the weld metal plays a part in determining weld quality, though a subordinate part compared with composition of base metal. Filler metal from covered electrodes generally is designed to have less than 0.20% C, often less than 0.10% C. Strength is increased by adding molybdenum (1/2%) or other alloying element. Filler metal in gas welding may have 0.1–0.3% C with sometimes 0.5% Si and 1.0% Mn. For reasons stated above, weld metal from a given electrode or rod will vary considerably in composition, and a considerable range of compositions prevails in practice.

Hot Cracks

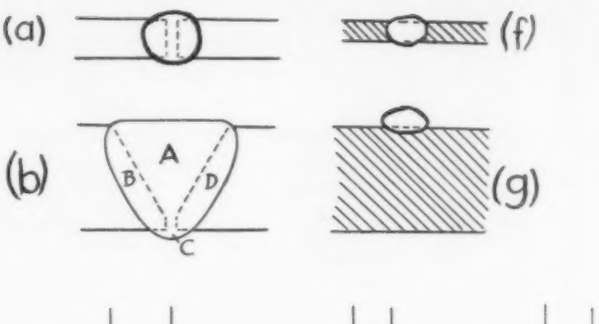
Referring to the section on "Tears" (Fig. 20) in Part III, Vol. II we deduce that any element promoting weakness in steel at temperatures just below the solidus should be excluded from, or at least maintained at a low per centage in, weld metal. Since carbon, phosphorus and sulphur exert the greatest influence in reducing ductility and strength just after solidification, they are held as low as possible. For example, A. S. T. M. Tentative Specifications for Iron and Steel Arc Welding Electrodes A 233–40 T limits the sulphur content of deposited metal to a maximum of 0.04%.

Hard Cracks

Hard cracks during welding do not occur even in the presence of a hard zone, if the weld metal has low yield strength and high capacity for deformation even in the presence of notches, such as at the root and toe of a fillet weld. Consequently, hard cracks are decreased by using filler metal having as low carbon and alloy content as possible. Since hard zones occur only in the higher-carbon and alloy steels, it is difficult, without using bare electrodes, to prevent the weld metal from picking up important quantities of carbon and alloying elements from base metal. So much can be done to ameliorate hard cracking by altering welding conditions without resorting to changes in filler metal composition, which at best shift the difficulty from hard zone to weld metal, that the subject will not be pursued further. Furthermore, high ductility of weld metal cannot protect hard zones from cracking under stress applied parallel to the zone, Fig. 19 (*c*).

Pick-Up

From the metallurgical standpoint the mixing of base metal with metal from the filler rod is most important



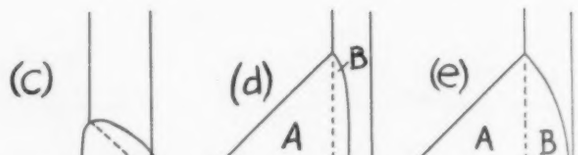


Fig. 45

(*a*) Unbeveled butt weld

(*b*) V butt weld; penetration percentage $= \frac{B+D}{A+B+C+D}$

(*c*) Single bevel *T* joint
(*d*) Low penetration percentage
(*e*) High penetration percentage
(*f*) Bead penetrating into sheet
(*g*) Bead of the same size barely penetrating below the surface of a thick plate

in governing the composition of the metal constituting the weld. The extent of the mixing is quoted as the percentage of the entire cross section of weld metal revealed by a macrograph that falls within the outlines of base metal before welding. To measure the percentage a cut is made through the weld perpendicular to both the direction of welding and the surface of the plates. The cut section is polished roughly with abrasive paper and is etched with 5% nitric acid, which reveals the boundary of the metal that has been melted during welding; that is, the weld metal.

Sections through several types of welds are shown in Fig. 45. The percentage of the entire cross section of weld metal falling within the initial outlines of base metal, which we shall call the "penetration percentage," is $100 \times \frac{B+C+D}{A+B+C+D}$, Fig. 45 (*d*). The penetration percentage is high for welds on thin sheet, Fig. 45 (*a*), for which little filler rod is required. Of course, if no filler rod is added the penetration percentage is 100%. With beveled scarves in thicker plate, Fig. 45 (*b*) and (*c*) the penetration percentage may be as low as 20%. The penetration percentage is 25% approximately in Fig. 45 (*d*) and 65% in (*e*).

Depositing the same electrode under identical conditions of current and speed will yield a higher penetration percentage on thin plate, Fig. 45 (*f*) than on thick plate (*g*), the reason for which will be found in Part I, Vol. II. Ordinarily the penetration percentage increases with the melting point of the electrode. Thus the penetration percentage will be nearly zero for a Tobin bronze electrode (melting point 800° C.) deposited on low-carbon steel, but will be high for a low-carbon steel electrode. A low-carbon steel electrode will exhibit a higher penetration percentage on cast iron (melting point 1150–1200° C.) than on steel (melting point = 1500° C.) under the same conditions of deposition. Penetration percentage is higher for neutral flame technique than for carburizing flame technique in the oxyacetylene welding of steel.

Penetration percentage governs pick-up with heavy

covered electrodes, for experiment has shown that with the sizes of beads ordinarily employed in arc welding, the composition is the same at all points over the cross section of the weld metal. Furthermore, experiment has confirmed the fact that with heavy covered electrodes, there is negligible loss (not over 10%) of carbon and alloying elements from the weld puddle. Let us calculate the pick-up in depositing a low-carbon steel electrode on medium-carbon steel with different penetration percentages. Assuming that the composition of weld metal deposited on a bed of weld metal from the same electrode is 0.10% C, 1.0% Mn, 0.5% Mo and that the base metal contains 0.30% C, 0.50% Mn, the weld metal will contain 0.20% C, 0.25% Mn, 0.25% Mo, if the penetration percentage is 50%, and will contain 0.15% C, 0.88% Mn, 0.38% Mo, if the penetration percentage is 25%.

If an austenitic electrode depositing weld metal containing 18.0% Cr, 8.0% Ni, 0.05% C is deposited on medium-carbon steel (0.30% C) with a penetration percentage of only 10%, the weld metal will contain 16.2% Cr, 7.2% Ni, 0.075% C, which is satisfactory, but if the penetration percentage rises to 33⅓% the weld metal will contain 12.0% Cr, 5.3% Ni, 0.13% C, which may not be sufficiently ductile. The calculation is not so satisfactory for materials of widely differing composition as for materials differing only slightly. In the example of the austenitic electrode deposited on plain-carbon steel, it is not certain that the weld metal is of uniform composition. In fact, at the junction between the mild steel and the austenitic weld metal there is always a thin zone of metal having a composition intermediate between weld metal and base metal.

It used to be a rule in welding that weld metal should have as nearly as possible the same composition as base metal. No longer does the rule apply, except for applications in which corrosion is a major factor. Austenitic electrodes are used to weld the higher-carbon steels where a hard zone is immaterial because it is removable by stress-relief heat treatment, but where cracked weld metal would be fatal. Bronze and Monel metal are used as filler metals for cast iron. Where corrosion is a factor it is wise to have weld metal of approximately the same composition as base metal. If it is desired to use an electrode of different composition, the weld metal should have considerably greater corrosion resistance than base metal, assuming, as is usually the case, that the area of weld metal exposed to the corrosive fluid is small compared with the area of base metal. Under these circumstances the base metal will not corrode appreciably faster than with weld metal of the same composition. With weld metal of inferior corrosion resistance, practically all corrosion will be concentrated on the welds, which will be eaten away rapidly. The metal of inferior corrosion resistance, for example bare electrode weld metal, forms an electrolytic cell with base metal. Being the anode of the cell, the bare electrode weld metal rapidly dissolves through electrolytic action.

Questions

1. Why is great emphasis placed upon the appearance of martensite in the vicinity of a weld, despite the fact that as the cooling rate is increased gradually, the mechanical properties of the steel also change without abruptness?
2. What is the connection between occurrence of martensite in the heat-affected zone and cooling rate or temperature gradient?
3. What elements in the composition of a steel may be responsible for hot cracks? cold cracks?
4. What are laminations, how are they detected, and what is their significance in welding?
5. State the composition, of four wrought low-alloy steels suitable for welding.
6. How may pick-up be calculated from measurements of penetration percentage?

Welding Positioner Table

By John S. Green*

IN ORDER to successfully compete in fabricating the wide variety of jobs that are called for, the small jobbing shop must rely on imagination and ingenuity in place of capital investment for special and sometimes intricate tooling.

Photograph illustrates the principle of a Revolving-Tilting Welding Positioner Table that can be built and used in the most modest jobbing shop. The positioner pictured was built when it became necessary to improve welding procedure in the fabrication of flanged pipe nozzles for pressure vessels.

After investigating the conventional type of positioners, it was decided to build an experimental machine in our own shop.

The answer to the question as to locating a satisfactory and cheap mechanism for the revolving member of the table was found in the suggestion that we use the front axle and wheel assembly of discarded automobile trucks. A trip to the graveyard of defunct automobiles disclosed the fact that there was an unlimited supply of such wheel assemblies that could be purchased at $1.50 each.

With one of these wheel assemblies as a basis for design, it took but a short time to sketch the required tilting and revolving positioner, that could easily be rotated with loads up to 1000 pounds.

Photo courtesy Hobart Brothers Company

* The Johnson and Jennings Company, Cleveland, Ohio.

When the sketch of positioner was sent to the welding shop, it was found that only the following material was required to be taken from stores material:

1 Steel base plate	1 in. x 34 in. diameter
1 Steel table top	1/2 in. x 36 in. diameter
1 Coil spring	1/8 in. wire 10 in. long
1 Steel yoke plate	3/4 in. x 12 in. x 16 in.

Balance of material required was found in steel scrap bins.

Little description of the photograph is required; a pin which registers with holes in the yoke, controlled by a foot pedal, gives the required angle at which to set the table; a pressure plate controlled by spring through levers to the foot pedal gives the operator full control of revolving the work as required—table was drilled for suitable clamps to hold work in position.

Cost of one positioner:	Material	$17.73
	Productive Labor (16 × 0.90)	14.40
	Total	$32.13

Three days after decision was made to build a welding positioner, the experimental one was completed and in service.

This same type of positioner is now being redesigned for use in the fabrication of an order for web and spoke wheels (16 in. and 20 in. diameter) to be used in the Defense program. About ten of these positioners will be required on which to weld spokes and webs in the wheels as they are taken from the set-up fixtures. On this job a power-driven table would be of no advantage as spokes interfere with welding a continuous bead.

Welding of Structural Steel*

By C. R. Owens†

ONLY a relatively few years ago the principal question surrounding the use of welding in the fabrication of steel structures was regarding the safety and reliability of the welding process. It would appear now that this question largely has been definitely settled in the minds of structural engineers, architects and code authorities as proved by the long and satisfactory safety record of the thousands of welded structures throughout the country. In recent years the widespread use of welding in the building of Naval vessels has done much to firmly establish this process of fabrication.

Today it is principally a question of proper technique of application and the coordination of the ideas and efforts of architects, structural steel engineers, welding supervisors and last, but not least, the welding operators.

The question is largely whether the designer understands the problems of the welder and so designs the joints of his structure that a welding operator of reasonable skill can produce a weld of satisfactory strength, appearance and cost at a reasonable speed. On the other hand, the operator and the welding supervisor should understand what the designer had in mind when he laid out the welded joint and try to make a weld that will satisfactorily produce the desired result at a minimum of labor cost.

From the operator's point of view, he has two choices of tools to make before he can guarantee making a satisfactory weld, namely, the choice of a proper electrode and the choice of an equipment to supply the arc.

Choice of the proper electrode to use in welding of structural steel to obtain the best results depends upon a number of considerations, such as:

1. The position in which the welding is to be done; whether flat, horizontal, vertical or overhead.
2. Thickness and cleanliness of the metal being welded.
3. Type of joint: whether fillet, butt, lap, etc. Also the preparation (such as V groove) and the fit-up of the pieces to be welded.
4. Type of welding equipment used, whether D.C. or A.C.

New A. W. S. Specifications (A-233-40T) are designed in such a way that class numbers indicate the type of power supply for which the electrode is suitable, the physical qualities the electrode metal deposit will meet, and the position in which the various classes of electrodes can be used as follows:

Class E-6010 is a D.C. reverse polarity electrode suitable for use in all positions of welding, and physical properties of deposited metal in as-welded condition are 65,000 lb. per sq. in. minimum and 22% elongation in 2 in. minimum.

Class E-6012 electrode is a direct current straight polarity or alternating current electrode suitable for use in all positions having physical properties of deposited metal meeting 65,000 lb. per sq. in. and 17% elongation in 2 in. as-welded.

Class E-6013 is an electrode especially designed for alternating current but which can be used on direct current usually with straight polarity suitable for welding in all positions and having physical properties of deposited metal meeting 65,000 lb. per sq. in. minimum and 17% elongation in 2 in. minimum.

Class E-6020 electrode is designed for alternating current or direct current straight polarity and can be used with either polarity for horizontal fillet and flat welding. This electrode deposits metal that meets 65,000 lb. per sq. in. minimum and 25% elongation in 2 in. minimum in as-welded condition.

Class E-6030 covers an electrode designed for alternating current or direct current straight polarity designed for flat welding only. Physical qualities of deposited metal are equal to 65,000 lb. per sq. in. minimum and 25% elongation in 2 in. minimum in the as-welded condition.

The new A. W. S. Specifications also include classifications for special low-alloy high tensile steel electrode and for bare and lightly coated electrodes.

Position.—The position in which joints are welded is one of the important considerations which affect both the choice of the electrode and the economies obtained by arc welding. For this reason designers should carefully analyze their work from a cost standpoint to ascertain if they are following practices which lead to the best over-all results. For instance, a 1/2-in. fillet may be welded in the overhead or vertical positions at the rate of 6–7 feet per hour, arc time. In the horizontal position the same joint may be made at the rate of 15–16 feet per hour, or over twice as fast. This saving in time results largely from the fact that larger electrodes of types providing faster melting rates can be used successfully. Maximum welding speeds, however, are realized in the flat position, where the 1/2-in. fillet welding speed

* Presented at the Feb. 13th Meeting, Los Angeles Section, A. W. S.
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may be as high as 25–28 feet per hour, or almost twice as fast as obtained in the horizontal position and four times as fast as obtained in the overhead and vertical positions.

In addition to savings, in arc time, positioning the work, where possible, will effect a further saving in labor costs. For instance, welding in the flat or horizontal positions is so much easier and less tiresome than overhead welding that the operator may be able to keep the arc in operation as much as twice as long per hour of over-all time. Likewise, vertical welding is less tiresome than overhead welding to the extent that the arc may be kept in operation as much as 50% longer per hour of over-all time without increasing operator fatigue.

With some types of structural steel work, of course, such as construction of buildings, ships, etc., the possibility of turning some joints into position is rather limited, if not out of the question. However, even the largest structure may be viewed as merely an assembly of sub-assemblies for which the advantages of positioning may be had to a greater or less degree. Therefore, the advantages of positioning the work should never be dismissed by the designer and fabricator without thorough analysis of the possibilities. Because the requirements of structural welding are generally such that a considerable per cent of the work is in the vertical and overhead positions, most structural fabricators are inclined to use an all-position type electrode for all of their work, rather than have several different types of electrodes on the job. However, in those jobs where there is a reasonably good per cent of flat or horizontal fillet welding to be done, it would pay the fabricators to investigate the advantages of Class E-6020 electrodes and Class E-6030 electrodes.

For instance, our Class E-6020 electrode provides a relatively heavy slag which helps the operator to produce excellent finished appearance in welding single-pass horizontal fillets and in making the finishing pass on multi-pass butt joints in the flat position. The contour of single-pass fillets is also better than that obtained with Class E-6010 or E-6012 electrodes. Either of the latter tend to produce fillets of convex contour, even in the flat or horizontal positions. This type of electrode tends to produce fillets of flat or concave contour which, of course, helps to avoid stress concentration at the toe of the fillet.

Our electrode (Class E-6030) provides a lighter slag than the E-6020 which helps the operator in producing excellent results when welding butt joints having U groove or J groove preparation. Under these conditions, the area to be covered by slag is restricted by the sides of the joint, so that the lighter slag provides adequate coverage and also makes it easier for the operator to keep the slag from running ahead of the arc. The molten deposit of this type also washes up well on the side walls, avoiding crevices where slag might be entrapped on the following pass.

Diameters.—In making horizontal fillet welds, the largest electrode normally recommended is 1/4 in. diameter, although a skilled operator can use 5/16 in. diameter without objectionable undercutting, particularly where large size fillets are being made. It is advisable to keep welding currents between the minimum and normal values recommended by the electrodes manufacturer when making horizontal fillets with 1/4-in. or 5/16-in. electrodes to avoid undercutting.

Fit-Up.—The above remarks are all on the basis of reasonably good fit-up of joints. Where poor fit-up conditions exist, an electrode of Class E-6012, which can be used in all positions, is recommended.

For vertical and overhead welding, 3/16-in. diameter is the largest rod that should be normally recommended. In fact, it is our practice to use 5/32 in. diameter all-position electrode on most vertical or overhead work. The flat position of welding ordinarily has no tendency to limit electrode. This is particularly true of alternating current welding. We have found that when using direct current, it is advisable to limit the maximum diameter of electrode to 5/16 in. in those places where magnetic disturbance is apt to occur, as a 3/8-in. electrode employs such large amperage value that, when welding with D.C. under conditions where magnetic disturbance of the arc occurs, it is practically impossible to produce a quality weld. The welder with A.C. arc avoids this magnetic disturbance or "arc blow," as it is called.

For best economy in welding heavy material (3/8 and thicker), the diameter of the electrode ordinarily should be as large as the position and joint preparation will permit. The advantage of using as large electrodes as possible under any set of conditions is illustrated by a comparison of deposition rates. For instance, a 1/4-in. electrode at 300 amperes has deposition rate of about 7 lb. per hour, arc time. With the same electrode in the 3/8-in. size at 530 amperes, the deposition rate is in the order of 15 lb. per hour. Since the arc time is the same in each case, it is evident that the 3/8-in. size saves welding labor at the rate of about 50% for each pound of metal deposited. With lighter material, the diameter of electrode ordinarily should not be greater than the plate thickness, unless the operator increases the travel speed sufficiently to prevent overheating, undercutting and burning through the metal.

In making vertical welds, it is recommended that a reverse polarity, all-position electrode be used, (Class E-6010), welding from the bottom up in order to insure uniformly adequate penetration. It appears significant that, for instance, Navy Specifications will not permit vertical welding to be done from the top down because a Class E-6010 electrode has an inherent tendency to leave pinholes in the weld when used for vertical welding downward. Some welding operators, if left to themselves, will lay vertical beads downward. The reason for this is that down welding enables them to use approximately 10% higher welding current, with corresponding higher welding speed, and it does give a smoother appearing weld. Penetration is sacrificed, however, and, generally speaking, this technique is not recommended.

A good all-position electrode of the Class E-6010 should have the following characteristics:

1. Ease of manipulation for vertical and overhead fillet and butt welds.
2. High speed.
3. Good contour and appearance of welds made in all positions.

One such electrode gave the following results using 3/16-in. electrode on single pass fillet welds on 3/8-in. plate.

Vertical position—100 amp. 29 volts deposited 3.3 lb./hr.
Overhead position—174 amp. 27 volts deposited 3.2 lb./hr.
Horizontal position—191 amp. 27 volts deposited 4.3 lb./hr.

Recommended current values for 5/32-in. all-position electrode would be:
Vertical—135 amp.
Overhead—140 amp.

Horizontal fillets and flat welding—150 to 170 amp. depending on the type of joint, thickness of work, etc.

Arc Welders

There are essentially 3 types of welders commercially available for structural steel welding:

1. Multiple-operator D.C. arc welders where 8 or 10 operators or possibly 50 operators are supplied with welding current from one welding generator.
2. Single-operator D.C. arc welders.
3. Single-operator A.C. transformer type arc welders.

Multiple-operator arc welders are particularly adaptable where 15 or 20 operators, or more, are concentrated in a rather restricted area, for work with electrodes of the same polarity. Their use is generally supplemented by a few single-operator welders to handle the flat position high current straight-polarity welding.

While multiple-operator sets have been used extensively for shop welding of structural steel, the writer does not recall any great use of them in the field so far as welding of buildings is concerned. However, they are being used extensively for the field welding of structural steel in shipyards, both in the launching ways and in the outfitting berths. These welders are generally driven by synchronous motors in order to improve the electrical power factor of the plant which usually is extremely low, due to use of lightly loaded induction motors throughout the plant.

The multiple-operator sets also have the advantage of generally showing a lower initial equipment investment than single operators of corresponding rating. A comparison recently made on the basis of supplying arcs to 60 operators showed a welding equipment cost of $14,600 for the multiple-operator sets and a cost of $23,700 for the single operator sets.

The cost of power for operating the multiple-operator sets generally is lower, particularly where the welding duty factor is low. Thus in the particular case mentioned above it would cost $12,500 a year for power for 60 arcs supplied from multiple-operator sets and $15,500 a year for the single-operator sets.

The cost of maintenance of a few large multiple-operator sets is generally agreed to be less than the maintenance of a great number of smaller single-operator sets.

The multiple-operator sets of nominal 1500-ampere capacity are generally used and larger current capacities are obtained by operating these sets in parallel. When thus operated the low duty cycle existing in most plants can be taken advantage of to supply the greatest number of operators from this welding system. In most shops the welding duty cycle averages about 40%. However, in shipyards it varies from about 10% for tack welding to about 35% for production welding and the over-all average is about 20–25%. On this basis a 1500-ampere multiple-operator set can supply arcs for about 30 operators using $^3/_{16}$-in. electrodes at 180 amperes average. The generators are usually operated flat-compounded at about 65 volts.

In this system of welding, adjustment of welding current for each individual operator's needs is made by providing each operator with a resistor station rated anywhere from 150 to 300 amperes. These resistors are each equipped with several knife switches by means of which current adjustment can be made in steps of 10–15 amperes. This is sufficiently fine adjustment for most purposes.

Single-operator D.C. welders are built in ratings of 150, 200, 330, 400 and 600 amperes. Each of these sets usually can be successfully operated up to 125% of its nominal ratings, for short intervals, and is provided with means of easily reversing polarity to use either straight or reverse polarity electrode, as needed. For shop welding they are available with induction motor drive. For field welding, where electric power is not available, these sets are driven by standard makes of internal combustion or of Diesel engines.

These sets have some advantages over multiple-operator sets, such as:

1. Finer adjustments of welding current, if necessary.
2. Individual sets can be more readily moved from place to place when the work is spread out over a wide area.
3. Where only a few arcs are needed in a plant, the economics of the case are in favor of single-operator sets instead of multiple-operator.

A.C. transformer type welders are available in ratings from 100 to 2000 amperes. The modern transformer type welder is a big improvement over the so-called "cracker-boxes" of years ago. These A.C. welders avoid the troublesome "arc blow" frequently encountered with D.C. welders at currents above 200 amperes, and thus permit welding current to be increased and larger electrodes to be used successfully. Welding speeds may be increased by 10–15%. Transformer type welders have no constantly moving parts to be kept lubricated and in working order. This largely accounts for the fact that they have practically no maintenance expense.

Because of their higher efficiencies, these welders save from 40–75% of the power required to operate welders of the rotating type. In the tabulation referred to above for providing arcs to 60 operators, the power cost in the case of the transformer welders is $7650 per year and $15,000 for the single-operator sets. These welders are now available with built-in capacitors so as to give electrical power factor. Their efficiency is about 80%, while the efficiency of single-operator sets is about 50%.

At one time welding operators were skeptical regarding the safety of A.C. welders of the transformer type. However, operators who have had experience with A.C. welders made by reputable manufacturers consider such welders no more hazardous to operate than rotating type welders. In many plants transformer-type welders are rapidly replacing the motor-generator sets.

The author wishes to acknowledge the assistance of his General Electric associates, H. O. Westendarp and W. E. Wilson, in the preparation of this material.

The Welding of the New Government Buildings, Stout Street, Wellington*

By R. G. Colvin†

Foreword

WHEN this paper was written it was thought that it would have local distribution only. In view of its publication in an overseas journal the writer feels that the history of the structure should be added, so that readers may appreciate the reasons for adopting this composite type of construction.

As a riveted structure the design of the steel frame had been completed and the steel ordered, when advice was received that the noise of the riveting would cause serious dislocation of business in the adjoining office buildings, and that an application for an injunction to prohibit riveting on the site would probably be successful.

The work being of an urgent nature, it was decided to alter the beam connections to allow arc welding; the column assemblies remaining as originally designed, except that field splices were welded instead of riveted.

Scope of the Paper

This paper deals with the practical side in the welding of typical connections, as set out in the engineering drawings and specifications supplied to the contractor, Messrs. Cable and Co. of Wellington. The scope of the paper is limited to the above, and does not deal with design or make any reference to other aspects of the work.

The paper is divided into two sections:

1. A typical beam to column connection.
2. A typical column splice connection.

These sections are subdivided into:

(*a*) Shop welding.
(*b*) Field welding.

Before commencing the first section it is advisable that a description of the method of building up the columns be given, so that the reader can appreciate the sequence of the work.

The columns are made up of three standard beam sections riveted together as shown in Sketch 1.

At each floor level cheek plates *a* and tee fins *b* are riveted as shown in Sketch 2, to carry the beam connections. This gives the cheek plates of a beam connection, in each of the four directions.

Where a column at a corner or outside wall requires it, it is a simple matter to drop the tee fins or shorten the cheek plates as the case may be. The tee fins are made by cutting a suitable size rolled steel joist down the web with the oxyacetylene cutting torch.

It is important to remember that these column sections are approximately 35 ft. long and cover 3 floors between splices. This has an important bearing on the methods used in the shop welding of the connections, as it was impossible in this instance to stand the columns in the vertical position for welding.

* Presented to the Wellington Branch, New Zealand Institute of Welding.
† Welding Inspector, P. W. D. Wellington.

Section 1. A Typical Beam to Column Connection

(*a*) *Shop Welding*

The shop work consisted of welding the beam bottom plate to the cheek plates of the connection; welding cheek plate stiffeners to the cheek plates; welding bottom shear block to the face of the column; welding beam top plate to top flange of the beam. (See Sketch 3.)

Shop Work on Connections.—The column is delivered to the welding shop from the riveters with the connections as shown in Sketch 2.

The beam bottom plate with four holes drilled in it for erection bolts and prepared as shown in Sketch 4 is held by means of a jig in position between the connection cheek plates for tacking. When tacked in each of the four corners the jig is removed and the welding commenced. These plates are butt welded with the completed weld having 10% greater cross-sectional area than the plate.

Welding Sequence.—The first two runs in each side of the butt weld were put in with No. 10 gage electrodes and welded in the vertical up direction. The column is then turned until the weld is horizontal and the weld is completed with No. 8 gage electrodes.

The connection cheek plate stiffener (Sketch 3) is then tacked and welded.

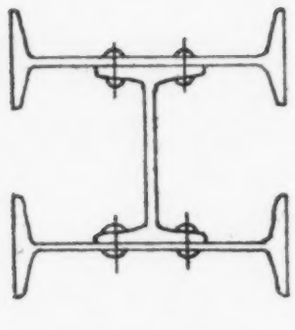
After the first two runs in the butt weld are completed, and before turning the column to complete the butt weld, the bottom shear block (Sketch 3) is located by means of a jig; tacked in such a position that when the beam is erected and the service bolts tightened the beam rests hard on the shear block and beam bottom plate. It is then fillet welded to the face of the column using No. 8 gage electrodes. This completes the shop welding on the column.

It may seem wrong to some people to put the first two runs in these butt welds in the vertical up direction when it was possible to turn the columns so that the weld could assume a horizontal position; so we will at this stage give the reason for adopting that method.

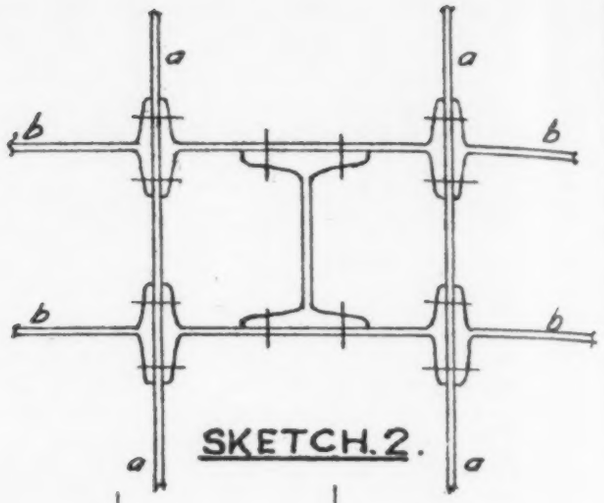
We all know that mild steel as rolled has a "skin" which is harder to penetrate with an electric arc than a cut edge of a plate. In this type of butt weld we have a beveled edge cut almost to a point, to be joined to the face of a plate which is not prepared in any way.

If we attempt to weld the plates in the position shown in Sketch 5 we have plate *a* requiring a fairly high amperage and plate *b* requiring considerably less to get equivalent penetration.

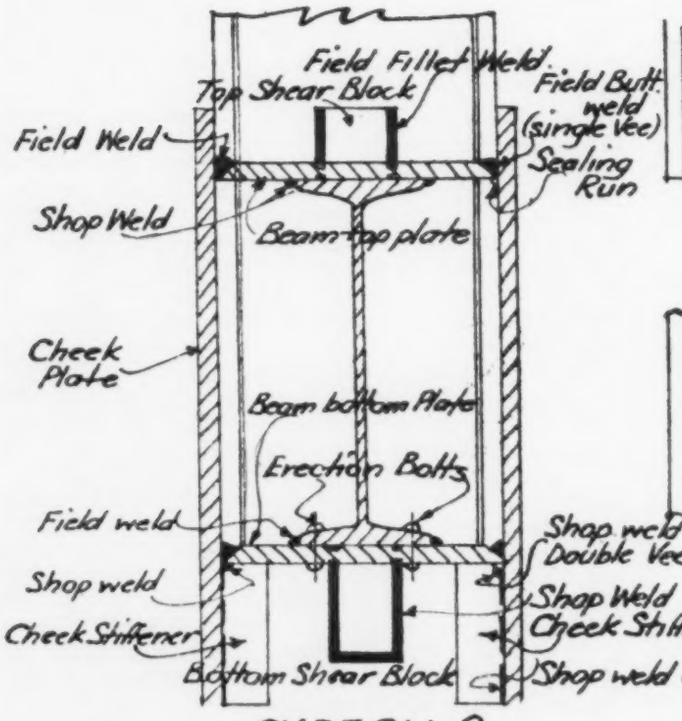
We must set our current high enough to penetrate plate *a* satisfactorily and when we have welded about an inch or so we find that the beveled edge of plate *b* cannot stand up to the heat generated by the arc and is melting away. The force of gravity is drawing the molten metal down to plate *a* and the slag being lighter takes the



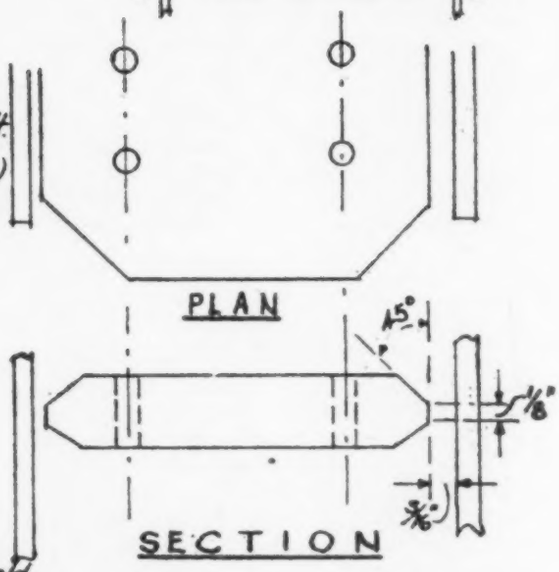
SKETCH 1



SKETCH. 2.



SKETCH 3



SKETCH .4.

place of the metal on the beveled edge. When the slag is chipped off we find that the plates are only joined in parts; the number of slag holes being considerable. If the amperage is lowered penetration is lost on plate *a*, the slag becomes sluggish and causes slag inclusions in the weld metal.

If we were butt welding edge to edge (Sketch 6) in this position all would be well because we have edges which require similar amperages to penetrate them and which give easy means of clearing the slag from the crater as the welding proceeds.

We found that by welding the first two runs in each side of the "vee" in the vertical up direction, 100% penetration was obtained, and at the same time it left the contour of the unfinished weld (Sketch 7) in such a shape as to make it an easy matter to complete the weld in the horizontal position with the No. 8 gage electrodes.

Shop Work on Beams.—The beams are cut to the correct length, the bottom flange drilled for erection bolts and delivered to the welding shop. The top flange plate (Sketch 3) is prepared as shown in Sketch 8.

The plate is located on the beam flange by means of a jig, tacked and then welded across the face of the flange. The beam is then turned upside down and the plate fillet welded to the edges of both flanges of the beam using No. 8 gage electrodes.

To prevent curling of the plate edges during welding a strongback (Sketch 9) is wedged in position; then two welders, one on each side of the beam, complete the weld. When the weld cools the strongback is removed and the beam is ready for delivery to the site.

(*b*) *Field Welding*

Field Work on Beam Connections.—The field work consists of fillet welding (overhead and horizontal) the bottom beam plate to the bottom flange of the beam; butt welding beam top flange plate to the cheek plate of the

connection and fillet welding (vertical) the top shear block to the face of the column, flush with the top of and in the center of the beam. (See Sketch 3.)

After the column is plumbed and the beam erection bolts tightened, a welder, using clamps and wedges, adjusts the gaps in the butt welds between the cheek plates of the connection and the beam top flange plate (Sketch 8) and tacks them securely.

Sequence of Runs in Butt Weld.—A copper backing strip is placed as shown in Sketch 10 and the first run is put in with a No. 10 gage electrode using a slightly higher than normal amperage. This helps in penetrating through the skin of the unprepared plate and lays the weld metal down on the copper strip, which tends to absorb heat from the weld metal rather rapidly.

This high amperage results in a certain amount of under-cutting in plate *a* (Sketch 10) and the second run must be concentrated on it to secure its complete elimination from the finished weld.

The third run is then put in alongside of run two.

All these three runs are made with No. 10 gage electrodes on account of the limited space at the bottom of the kerf when one of the plates has no bevel on it. After these three runs have been put in, the kerf is usually accessible to No. 8 gage electrodes at normal amperage. The operator now carries on with these and completes the butt weld.

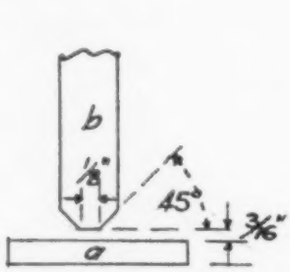
The cross-sectional area of the weld is 10% greater than the cross-sectional area of the plate.

A point worth stressing is that in filling a kerf in a butt weld of this kind it is essential that each layer of weld metal be reasonably light runs and that the first run of each layer be up against the unprepared plate (*A*, Sketch 10). If the operator works from the beveled plate to the unprepared one with each layer he runs the risk of trapping slag and losing penetration on the unprepared plate.

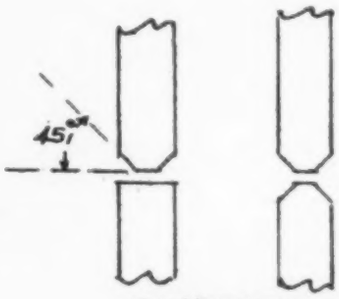
The top portion of the butt weld being now complete the underneath side is cleaned up and an overhead sealing run put in. If the first run from the top, in the bottom of the "vee," has been wide it is sometimes necessary to put in two runs overhead in order to completely cover that run and reach the parent metal (Sketch 11). This completes the butt weld.

The bottom flange of the beam is then fillet welded (overhead and horizontal) to the beam bottom plate of the connection using No. 8 gage electrodes. The erection bolts can then be removed.

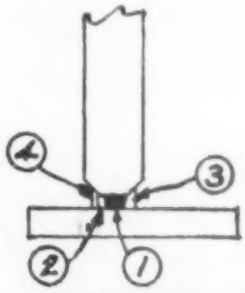
The next operation is to fillet weld (vertical) with No. 10 gage electrodes the top shear block on the top of



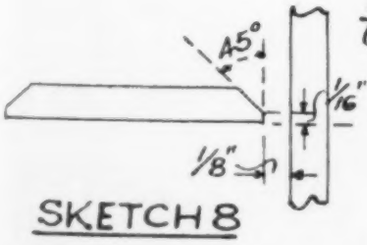
SKETCH 5.



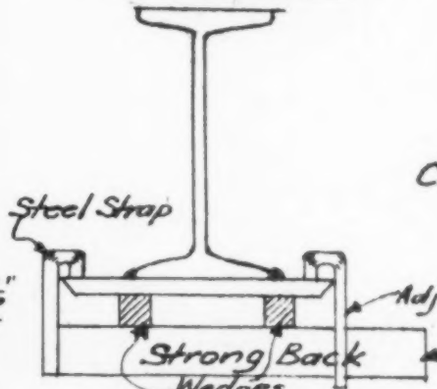
SKETCH 6



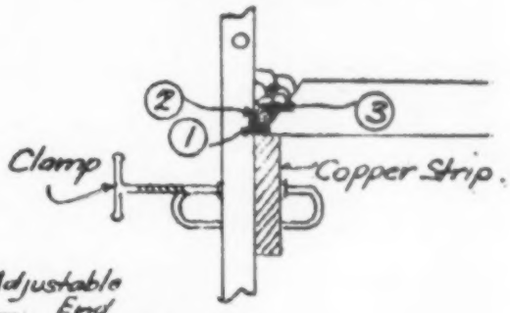
SKETCH 7



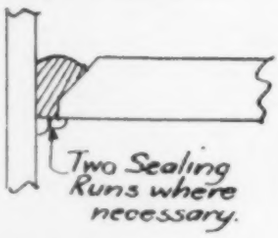
SKETCH 8



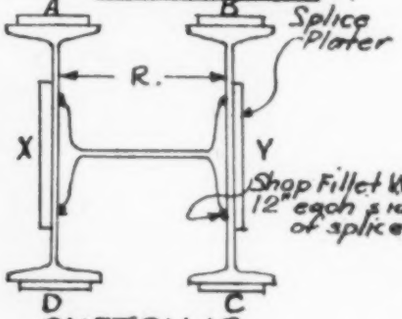
SKETCH 9



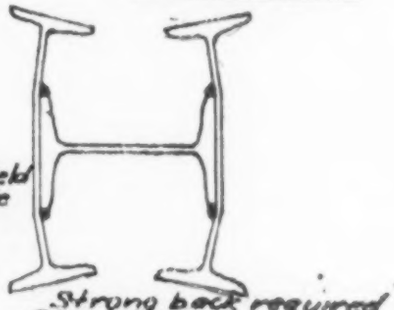
SKETCH 10



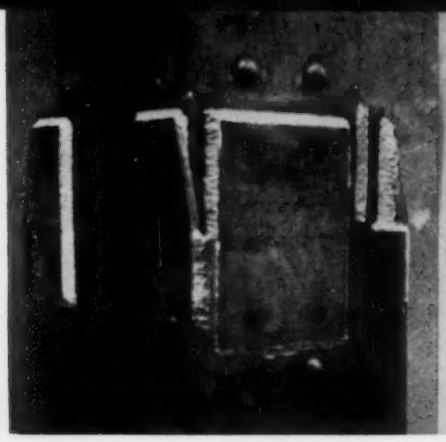
SKETCH 11

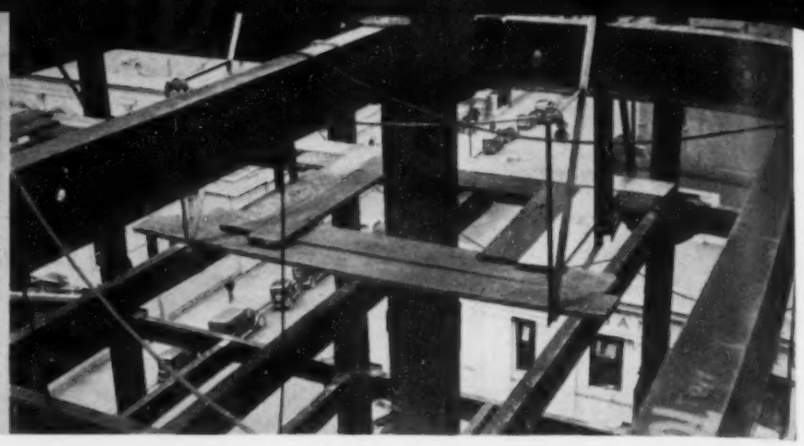


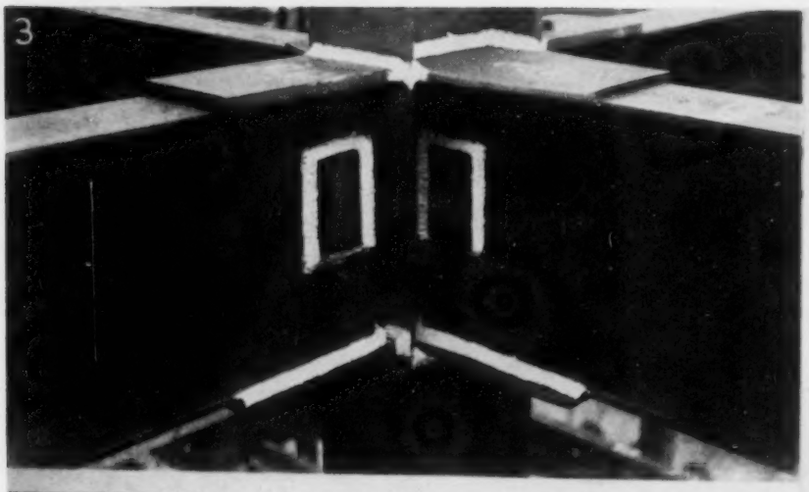
SKETCH 12

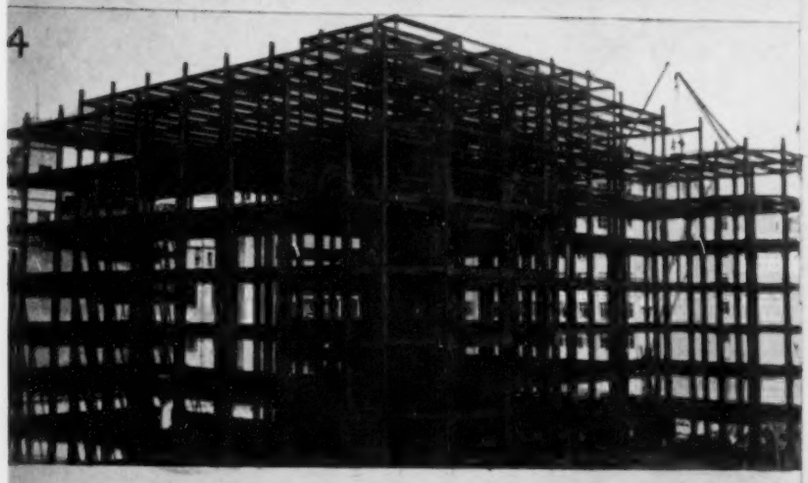


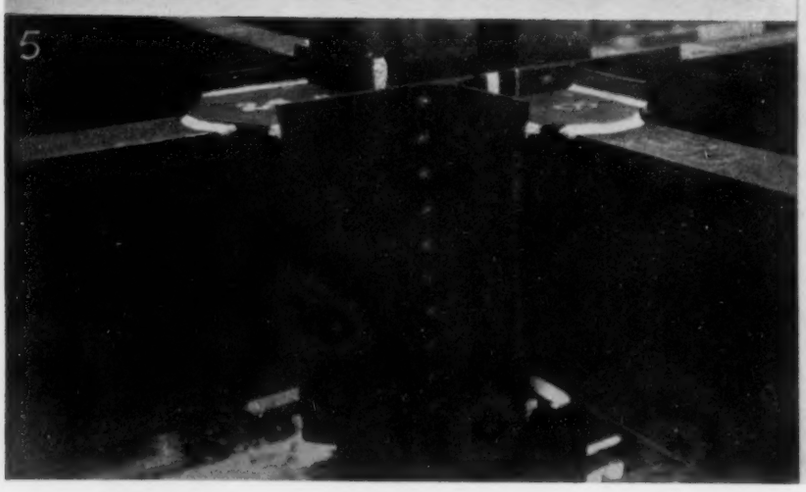
SKETCH 13.

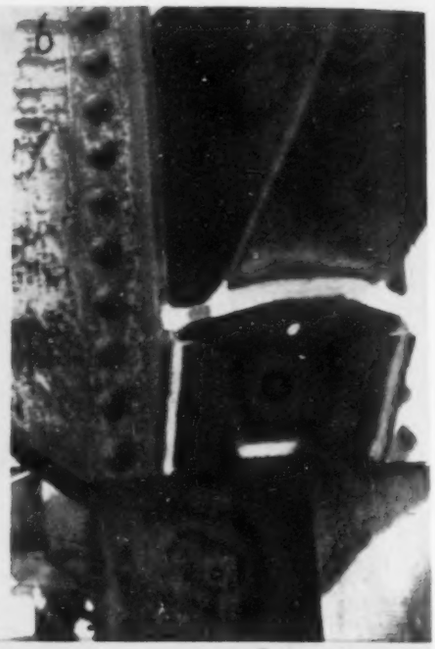


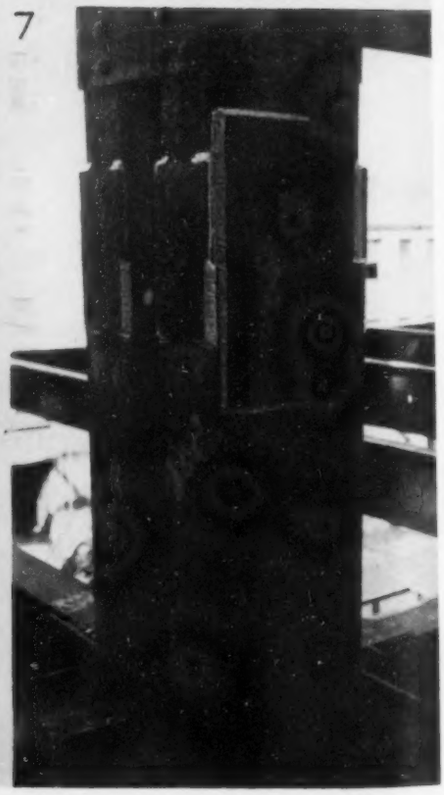




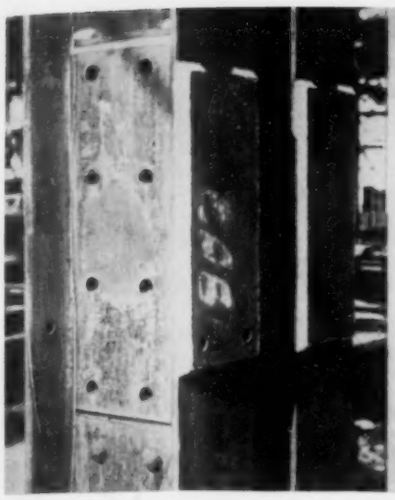




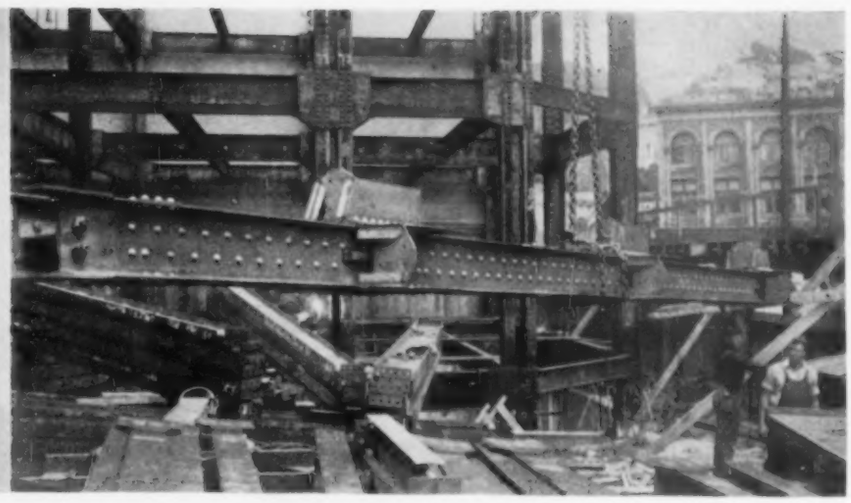




1. Column Splice, Corner Columns Only, at 5th Floor Level
2. Welder's Scaffold
3. Beam to Column Connections at Roof Level
4. Completed Structure
5. Typical Beam to Column Connection Ground to 7th Floor
6. View Underneath a Typical Beam to Column Connection Ground to 7th Floor
7. Column Splice at 2nd Floor Level



8. Column Splice at Ground Floor Level



9. Column Sections as Delivered to Site from the Shops, Bottom End Nearest Camera

and in the center of the beam to the face of the column.

This completes the connection and after inspection the welder passes on to the next connection.

It should be noted that a welder usually has more than one connection to do on each column at every floor level and thus he can spread his work around several connections to allow the heat generated by the arc to be radiated away, thus preventing any possibility of complications due to overheating, etc.

Section 2. A Typical Column Splice Connection

(*a*) *Shop Welding*

Before detailing the shop and field work on the column splices, it would be as well to describe the various parts of the splice.

The columns are made up of three rolled steel sections as shown in Sketch 1 and at the splices are milled and ground on the ends to ensure a close fit.

The outer rolled steel sections have flange plates *A*, *B*, *C*, *D*, extending about four inches above and below the joint; also web plates *X* and *Y* extending about twelve inches above and below the joint. (See Sketch 12.) These plates are fillet welded to the columns.

Plates *A*, *B*, *C* and *D* are shop welded to the bottom end of the upper section of the column and field welded to the top end of the lower section. The web plates *X* and *Y* are field welded to both upper and lower sections of the column owing to the fact that dimension *R* (Sketch 12) may vary slightly and if the upper section of the column happened to be a fraction narrower than the lower section erection would be difficult as plates *X* and *Y* are of heavy section.

The flanges of the central stanchion member are shop welded (fillet) to the inside of the webs of the outer stanchion members for the length that the rivets must be left out to allow the web splice plates *X* and *Y* to sit flush on the face of the column.

Sequence of Shop Welding.—While the work on the connections is proceeding in the shop an operator is working on each end of the column section preparing it for the splice. As the column is rolled he welds the various parts, thus keeping all welding in the horizontal position.

First the flanges of the central stanchion member are fillet welded to the inside of the webs of the outer rolled steel sections. If care is not taken the flanges will "toe in" as shown in Sketch 13.

A restraining jig was made to slip over the end of the column and the flanges wedged back to prevent them twisting.

After these welds have cooled the jig is removed and the flange splice plates *A*, *B*, *C*, *D* (Sketch 12) are fillet welded to the bottom end of the upper section of the splice.

This completes the shop welding on the splice.

(*b*) *Field Welding*

After the column has been plumbed, flange plates *A*, *B*, *C* and *D* and web plates *X* and *Y* are "laid up" against the column by means of erection bolts and fillet welded, the web plates *X* and *Y* being welded all round and the flange plates *A*, *B*, *C* and *D* being welded up the sides (vertical) and turned 1 inch around the top and bottom edges.

The welding consisted of fillet welds only. In the vertical welds the first run was made with a No. 10 gage electrode and the remainder of the fillet built up with No. 8 gage electrodes. All vertical welds were made in the up direction.

The overhead and horizontal fillet welds were made with No. 8 gage electrodes.

Toward the roof of the building as the columns are reduced in size the shape of the splice alters slightly but the principle of flange and web plates remains. The method of welding is similar and no good purpose would be served in making a lengthy description of them.

Below are a few figures in connection with the field work which may be of interest to readers.

Electrodes used in field—271,100 ft.
Number of manhours worked by welders—14,906 manhours.
Consumption of electric current—51,317 kw.-hr.
Average number of welders employed on site—10.
Maximum number of welders employed on site—16.

Before concluding the writer would like to pay a small tribute to the welding operators. The cooperation that was received from the foreman right down to the last man was excellent and speaks volumes for the future of the welding industry in New Zealand.

Acknowledgment

The writer wishes to express his appreciation to Mr. V. A. Murphy, A. M. Inst. C. E., for the preparation of the necessary sketches.

STANDARD QUALIFICATION PROCEDURE*

Section I

Manual Arc and Gas Welding of Ferrous Materials

FOREWORD

It is recognized that the quality of arc- and gas-welded joints will be determined by the specific welding procedure used and by the ability of the welding operator to apply that procedure. Predictable results as to the physical properties and soundness of such joints can be secured only by adherence to a procedure of welding that has been thoroughly investigated. It cannot be expected that good results will be obtained, even by careful and painstaking workmen, if poor material, inadequate or worn out equipment are used, or if fundamentally improper methods are pursued. Nor can the purpose of welding be obtained by the mere adoption of a carefully outlined procedure of welding, if the welding operators have not been given a certain degree of training and are not properly supervised to be certain that all essential details of the specific procedure for welding are followed.

In arc and gas welding, the physical properties of the weld metal, such as tensile strength and ductility, will be determined by the particular procedure of welding that is used. The reliability of the welded joint will be determined by the degree to which that weld metal is kept free of foreign materials, such as slag, and by the degree to which it is fused to the base material. Under a fixed procedure of welding these two latter factors are the only ones over which the welding operator has control. It is considered unnecessary, therefore, to test welds of every operator for tensile strength and ductility. It is the belief of the Committee that the first step in welding must be the adoption of a procedure of welding in which all essential variables are fixed within definite limits. The procedure for welding should then be investigated to determine whether it will produce welds with the desired physical properties. The tests required for a welding operator are included in the investigation of a welding procedure because there have been many instances wherein failure to obtain results has been attributed to the inability of the operator when the difficulty lay in the fundamentals of the procedure. Having established that a given procedure is satisfactory, comparatively simple tests, intended primarily to determine the ability of an individual to make a sound weld, may then be used for the qualification of welding operators.

In Part I there is given the method to be pursued in investigating and qualifying a welding procedure, while Part II outlines the method of qualifying welding operators.

There are several variables involved in any procedure of welding, and if predictable results are to be obtained, certain limitations must be placed upon those variables before the procedure for welding is tested. Having fixed upon these limitations, it is necessary that some tolerance or degree of departure from a given limitation of a variable, as stated in a procedure specification, be recognized as permissible without requiring that a retest of the procedure be made. Such departures from a fixed procedure of welding as might affect the predictable results to be obtained, may be referred to as essential changes. The tests which must be made to determine the effect that a given essential change will have upon the predictable results will depend upon the nature of that change. In some cases a test of the procedure for welding, embodying the change, will be necessary, in other cases a test of the welding operator only will be sufficient, and in still other cases a test of both the new procedure and the individual operators will be required.

A tabulation of the variables and of those changes in variables which are considered to be essential changes, together with the type of investigation necessary—whether of procedure, operator or both—is given in Article 101.

The Committee has given much thought to the need for simplification of the test of a welding operator, and the type of tests outlined herein are designed to ascertain that the operator has a sufficient knowledge of and the skill to apply a procedure of welding under average conditions. For this purpose, a special shape of welding groove, intended to be used only for operator test specimens, has been adopted.

The Committee has also been seeking and now presents a type of operator test specimen for fillet welded joints that may be readily tested in a guided bend test jig, thus providing a test that is not only inexpensive and simple to make, but also one that avoids question of judgment as to the results obtained.

It is the conviction of the Committee that there are so many essential factors involved in the successful application of arc and gas welding, embracing such items as quality of filler metal, adaptability of the welding procedure and equipment, facilities provided for preparing the work, etc., that the manufacturer or contractor alone should be expected to be responsible for the integrity of the finished weld. It should be borne in mind that it is the manufacturer or contractor who is financially responsible for the quality of the welding performed and that in the case of failure thereof the welding operator assumes no share of the financial burden. In these rules, therefore, the entire responsibility for quality of the welding performed will be assumed to lie with the manufacturer or contractor.

The Committee will be pleased to provide any interpretations that may assist in the application of this standard.

GENERAL

These rules are intended to apply only to the manual application of the arc- and gas-welding processes, and to those ferrous metals which in their unwelded condition will meet the requirements of the guided bend test prescribed herein.

Each manufacturer or contractor shall be responsible for the quality of the welding done by his organization and shall conduct tests not only of the welding procedure to determine its suitability to ensure welds which will meet the required tests, but also of the welding operators to determine

* Prepared by the Committee on Standard Qualification Procedure and Committee on Grouping of Materials for Procedure and Operator Qualification.

Approved by Executive Committee April 25, 1941.

P 6 An increase in the diameter of the electrode or welding rod used,

meet the required tests, but also of the welding operators to determine their ability to make sound welds under standardized test conditions.

It is assumed that the manufacturer or contractor has an organization familiar with the various welding codes and capable of designing, engineering and supervising welded construction.

Rules for the qualification of a welding procedure are given in Part I. Rules for qualifying operators follow in Part II.

PART I—PROCEDURE QUALIFICATION

101. Limitation of Variables

(*a*) The procedure of welding to be followed in construction shall be established and recorded by the manufacturer or contractor as a Procedure Specification, and in the investigation to qualify this procedure, the Procedure Specification shall be followed. Recommended forms for the Procedure Specification are given in the Appendix. It is not necessary that these exact forms be used, but the information contained therein should be set forth in any alternate form which is adopted.

(*b*) If any changes are made in a procedure, the Procedure Specification shall be revised or amended to show these changes.

The changes set forth in the following schedule shall be considered essential changes and shall require requalification of the procedure or operator or both. Any change marked "P" or "PO" shall require requalification of the procedure; any change marked "PO" or "O" shall require requalification of the operator.

P	1	A change in the specification of base metal to be welded from one "P" Number to another "P" Number. (See Table 5.)*
PO	2	A change in the specification of base metal to be welded from one "O" Number to another "O" Number. (See Table 5.)
PO	3	A change in filler metal from one American Welding Society Specification** to another Specification.
P	4	A change in filler metal from one American Welding Society Classification Number† to another American Welding Society Classification Number.
O	5	A change in filler metal from a bare or lightly coated electrode to a covered electrode, or vice versa, within any given American Welding Society specification for arc welding electrodes.‡
P	6	An increase in the diameter of the electrode or welding rod used, over that called for in the Procedure Specification.
P	7	A change of more than 15 per cent above or below the specified mean arc voltage and amperage for each size electrode used.
P	8	For a specified welding groove, a change of more than plus or minus 25 per cent in the specified number of passes. If the area of the groove is increased, it is also permissible to increase the number of passes in proportion to the increased area.
PO	9	A change in the position in which welding is done as defined in Articles 104 and 204.
O	10	In the case of vertical welds, a change from the progression specified for any pass from upward to downward or vice versa.
P	11	A decrease in the preheating temperature.
P	12	A change in the heat-treating temperature range or time range.
P	13	A change in the specified range of sizes of gas-welding tips.
P	14	A change of gas-welding flame from neutral to one with an excess of acetylene or vice versa.
O	15	A change from the "backhand" to the "forehand" method of welding. (Gas or carbon arc welding.)
P	16	A decrease in the number of layers used in gas welding.
P	17	A change in the type of welding groove. (Example, change from a V to a U shape.)
P	18	A change in the shape of any one type of welding groove involving: (1) a decrease in the included angle of the welding groove, or a decrease in the width of the groove; or (2) a decrease in the root opening of a welding groove; or (3) an increase in the root face of a welding groove; or (4) the addition or omission of a backing strip.

* When any "P" group in Table 5 contains materials having specified minimum tensile strengths higher than the tensile strength obtained in the actual procedure qualification tension test, it may be desirable for governing codes to require procedure qualification using these higher tensile materials before they can be welded in actual construction.

** See American Welding Society filler metal specifications.

† For example: A change from an E6010 to an E6012 or E7010 electrode (Tentative Specifications for Iron and Steel Arc Welding Electrodes); or a change from a G60 to a G45 or G65 welding rod (Tentative Specifications for Iron and Steel Gas Welding Rods).

‡ For example: A change from an E6010 to an E4510 electrode requires requalification of the operator; a change from an E6010 to an E6020 or E6030 electrode *does not* require requalification of the operator (Tentative Specifications for Iron and Steel Arc Welding Electrodes).

102. Types of Tests and Purposes

The types of tests outlined below are to determine the tensile strength, ductility and degree of soundness of welded joints made under a given Procedure Specification. The tests used are as follows:

(*a*) *For Groove Welds*

(1) Reduced-Section Tension Test (for Tensile Strength)
(2) Free-Bend Test (for Ductility)
(3) Root-Bend Test (for Soundness)
(4) Face-Bend Test (for Soundness)
(5) Side-Bend Test (for Soundness)

(*b*) *For Fillet Welds*

(1) Longitudinal or Transverse Shear Test (for Shear Strength)
(2) Free-Bend Test (for Ductility)
(3) Fillet-Weld-Soundness Test (for Soundness)

103. Base Material and Its Preparation

The base material and its preparation for welding shall comply with the

Procedure Specification.* For all types of welded joints the length of the weld and the dimensions of the base material shall be such as to provide sufficient material for the test specimens called for hereinafter.

104. Position of Test Welds

All welds that will be encountered in actual construction, except groove welds in pipe, shall be classified as being (1) Flat, (2) Horizontal, (3) Vertical or (4) Overhead, in accordance with the definitions of welding positions given in Fig. 1 (*a*) and 1 (*b*). Groove welds in pipe shall be classified as (1) Horizontal Rolled, (2) Horizontal Fixed or (3) Vertical, in accordance with the definitions of pipe welding positions given in Fig. 1 (*a*). Each procedure shall be tested in the manner stated below for each position for which it is to be qualified.

(*a*) *Groove Welds in Plate*

In making the tests to qualify groove welds in plate, the test plates shall be welded in the following positions:

(*1*) *Flat Position*—The test plates shall be placed in an approximately horizontal plane and the weld metal deposited from the upper side. (Illustrated in Fig. 21 (*a*).)

(*2*) *Horizontal Position*—The test plates shall be placed in an approximately vertical plane with the welding groove approximately horizontal. (Illustrated in Fig. 21 (*b*).)

(*3*) *Vertical Position*—The test plates shall be placed in an approximately vertical plane with the welding groove approximately vertical. (Illustrated in Fig. 21 (*c*).)

(*4*) *Overhead Position*—The test plates shall be placed in an approximately horizontal plane and the weld metal deposited from the under side. (Illustrated in Fig. 21 (*d*).)

(*b*) *Groove Welds in Pipe*

In making the tests to qualify groove welds in pipe, the pipe shall be welded in the following positions:

(*1*) *Horizontal Rolled*—The pipe shall be placed with its axis in an approximately horizontal plane with the welding groove in an approximately vertical plane and the pipe shall be rolled during welding. (Illustrated in Fig. 21 (*a*).)

(*2*) *Horizontal Fixed*—The pipe shall be placed with its axis in an approximately horizontal plane with the welding groove in an approximately vertical plane and the pipe shall not be rolled or turned during welding. (Illustrated in Fig. 21 (*e*).)

(*3*) *Vertical*—The pipe shall be placed with its axis in an approximately vertical position with the welding groove in an approximately horizontal plane. (Illustrated in Fig. 21 (*b*).)

* To avoid misleading results it is desirable that the base material used in the qualification of a procedure contain amounts of carbon, manganese, chromium, molybdenum and other alloys approaching the maximum quantities of these elements which may be present in the materials that will be welded in actual construction.

(*c*) *Fillet Welds*

In making the tests to qualify fillet welds in plate, the test plates shall be welded in the positions outlined below. (If fillet welds are to be made in pipe, they shall be qualified by tests made in plate unless other tests are specifically provided for by a governing Code.)

(*1*) *Flat Position*—The test plates shall be so placed that each fillet weld is deposited with its axis approximately horizontal and its throat approximately vertical. (See Fig. 2 (*a*).)

(*2*) *Horizontal Position*—The test plates shall be so placed that each fillet weld is deposited on the upper side of the horizontal surface and against the vertical surface. (See Fig. 2 (*b*).)

(*3*) *Vertical Position*—Each fillet weld shall be made vertically. (See Fig. 2 (*c*).)

(*4*) *Overhead Position*—The test plates shall be so placed that each fillet weld is deposited on the under side of the horizontal surface and against the vertical surface. (See Fig. 2 (*d*).)

NOTE: The above arrangement of test plates refers only to the making of the fillet welds. The closing weld between fillet welds in the fillet-weld-soundness test may be made in any position.

105. Number of Test Welds Required

(*a*) *Groove Welds in Plate or Pipe*

For groove welds in material up to and including $^3/_4$ in. thick, one test weld shall be made in material $^3/_8$ in. thick* for each procedure and position to be used in construction, except that if the construction involves welding of material over $^3/_4$ in. thick, a test weld shall be made in material of the maximum thickness* to be used in construction for each procedure and position, but which need not exceed 1 in.* If a test is made in the maximum or 1 in. thickness, no test need be made in the $^3/_8$ in. thickness. In the case of pipe, the nominal diameter of the pipe used for the test weld shall not be less than 6 in.

(*b*) *Fillet Welds*

For fillet welds two longitudinal or two transverse shear test welds shall be made for each procedure and position to be used in construction. For each type of test weld, one shall be made with the maximum size single-pass fillet weld and one with the minimum size multiple-pass fillet weld that will be used in construction. In addition, one test weld for the free-bend and fillet-weld-soundness tests shall be made with the maximum size single-pass fillet weld (not over $^3/_8$ in.) that will be used in construction, for each procedure and position to be used in construction.

106. Welding Procedure

The welding procedure shall comply in all respects with the Procedure Specification.

* In the case of pipe, the wall thickness may vary + or $-12^1/_2$ per cent from that indicated.

107. Test Specimens—Number, Type and Preparation

108. Method of Testing Specimens

(*a*) *Reduced Section Tension Specimens*

present in the materials that will be welded in actual construction.

indicated.

107. Test Specimens—Number, Type and Preparation

(a) Groove Welds

For groove welds in plate the method of preparing the specimens shall be in accordance with the figures referred to in Table 1 and the number of tests required shall be as given in the table. The test specimens shall be removed in the order given in Figs. 10 and 11.

For groove welds in pipe the method of preparing the specimens shall be in accordance with the figures referred to in Table 2 and the number of tests required shall be as given in the table. The test specimens shall be removed in the order given in Figs. 15 and 16.

TABLE 1—PROCEDURE QUALIFICATION TESTS FOR GROOVE WELDS IN PLATE

Maximum Thickness to Be Welded in Construction	Test Plate Thickness	Number and Type of Tests Required				
		Reduced-Section Tension. (See Fig. 6)	Free-Bend. (See Fig. 7)	Root-Bend. (See Fig. 8)	Face-Bend. (See Fig. 8)	Side-Bend. (See Fig. 9)
Up to and including 3/4 in.	3/8 in.	2	2	2	2	..
Over 3/4 in.	Maximum, but need not exceed 1 in.	2	2	..	..	4

TABLE 2—PROCEDURE QUALIFICATION TESTS FOR GROOVE WELDS IN PIPE

Maximum Thickness to Be Welded in Construction	Test Pipe Wall Thickness	Number and Type of Tests Required				
		Reduced-Section Tension. (See Fig. 12)	Free-Bend. (See Fig. 13)	Root-Bend. (See Fig. 14)	Face-Bend. (See Fig. 14)	Side-Bend. (See Fig. 9)
Up to and including 3/4 in.	3/8 in.	2	2	2	2	..
Over 3/4 in.	Maximum, but need not exceed 1 in.	2	2	..	..	4

(b) Fillet Welds

The longitudinal shear test specimens shall be welded as shown in Fig. 3 and prepared for testing as shown in Fig. 17. The transverse shear test specimens shall be made as shown in Fig. 4.

The test weld for the free-bend and soundness tests shall be made as shown in Fig. 5. From the test weld there shall be taken two free-bend test specimens, which shall be prepared for testing as shown in Fig. 7, and two fillet-weld-soundness test specimens as shown in Fig. 20.

108. Method of Testing Specimens

(a) Reduced-Section Tension Specimens

Before testing, the least width and corresponding thickness of the reduced section shall be measured in inches. The specimen shall be ruptured under tensile load and the maximum load in pounds shall be determined. The cross-sectional area shall be obtained as follows: cross-sectional area = width × thickness. The tensile strength in pounds per sq. in. shall be obtained by dividing the maximum load by the cross-sectional area.

(b) Free-Bend Test Specimens

The gage lines indicated in Fig. 7 shall be lightly scribed on the face of the weld. The gage length (distance between gage lines) shall be approximately 1/8 in. less than the width of the face of the weld, and shall be measured in inches to the nearest 0.01 in.

Each specimen may be bent initially by the use of a fixture complying with the requirements of Fig. 18. The surface of the specimen containing the gage lines shall be directed toward the supports. The weld shall be at midspan of both the supports and the loading block. Alternatively, the initial bend may be made by holding each specimen in the jaws of a vise with one-third the length of the specimen projecting from the jaws, then bending the specimen away from the gage lines through an angle of from 30 to 45° by blows of a hammer. The other end of the specimen shall be bent in the same way. In order that the final bend shall be centered on the weld, the initial bends shall be symmetrical with respect to the weld, and both ends shall be bent through the same angle. The initial bend may also be started at the weld by placing the specimen in the guided-bend test jig shown in Fig. 19.

Compressive forces shall be applied to the ends of the specimen, continuously decreasing the distance between the ends. (Any convenient means such as a vise or a testing machine may be used for the final bend.) When a crack or other open defect exceeding 1/16 in.* in any direction appears on the convex face of the specimen, the load shall immediately be removed. If no crack appears, the specimen shall be bent double. Cracks occurring on the corners of the specimen during testing shall not be considered.

The elongation shall be determined by measuring the minimum distance between the gage lines, along the convex surface of the weld, to the nearest 0.01 in. and subtracting the initial gage length. The per cent elongation shall be obtained by dividing the elongation by the initial gage length and multiplying by 100.

(c) Root-, Face-, Side-Bend and Fillet-Weld-Soundness Specimens

Each specimen shall be bent in a jig having the contour shown in Fig. 19, and otherwise substantially in accordance with that figure. Any convenient means may be used for moving the male member with relation to the female member.

The specimen shall be placed on the female member of the jig with the weld at midspan. Face-bend specimens shall be placed with the face of the weld directed toward the gap; root-bend and fillet-weld-soundness specimens shall be placed with the root of the weld directed toward the gap; side-bend specimens shall be placed with that side showing the greater

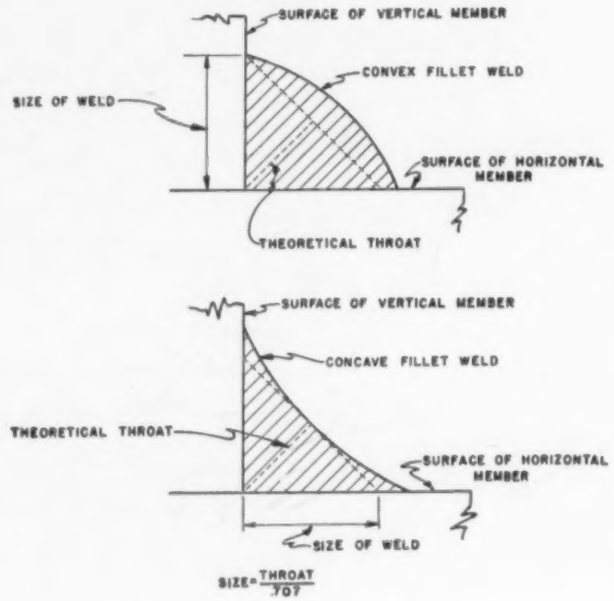
* See Note I, Art. 109.

defects, if any, directed toward the gap. The two members of the jig shall be forced together until the curvature of the specimen is such that a $^1/_{32}$-in. diameter wire cannot be passed between the curved portion of the male member and the specimen. The specimen shall then be removed from the jig.

(*d*) *Longitudinal and Transverse Shear Test Specimens*

Before testing, the length of the individual welds shall be measured in inches and if any weld varies by more than $^1/_{16}$ in. from the length specified in Figs. 4 and 17, then the length of each weld and its location shall be recorded. The average size of the fillet welds shall also be recorded. The specimen shall be ruptured under tensile load and the maximum load in pounds shall be determined. The shearing strength of the welds in pounds per linear inch shall be obtained by dividing the maximum force by the sum of the lengths of the welds which ruptured. The shearing strength of the welds in pounds per sq. in. shall be obtained by dividing the shearing strength in pounds per linear inch by the average theoretical throat dimension of the welds in inches.

NOTE: The size and theoretical throat dimension of a fillet weld shall be defined as illustrated in the sketch below. The size of a fillet weld is the leg length of the largest inscribed isosceles right triangle. The theoretical throat dimension may be obtained by multiplying the size of the fillet weld by 0.707.



109. Test Results Required

The requirements for the test results shall be as follows:

(*a*) *Reduced-Section Tension Test*

The tensile strength shall be not less than 100 per cent of the minimum of the specified tensile range of the base material used. (See Notes I and III.)

(*b*) *Free-Bend Test*

The elongation shall be not less than 30 per cent for stress-relieved welds nor less than 25 per cent for non-stress-relieved welds. (See Notes I and III.)

(*c*) *Root-, Face-, Side-Bend and Fillet-Weld-Soundness Tests*

The convex surface of the specimen shall be examined for the appearance of cracks or other open defects Any specimen in which a crack or other open defect is present after the bending, exceeding $^1/_8$ in. measured in any direction, shall be considered as having failed. Cracks occurring on the corners of the specimen during testing shall not be considered. (See Notes I and III.)

(*d*) *Longitudinal or Transverse Shear Test*

For the longitudinal shear test specimen the shearing strength of the welds in pounds per square inch shall be not less than $^2/_3$ of the minimum of the specified tensile range of the base material. For the transverse shear test specimen the shearing strength of the welds in pounds per sq. in. shall be not less than $^7/_8$ of the minimum of the specified tensile range of the base material. (See Notes I, II and III.)

NOTE I: These values as set forth shall apply where no Code is in effect, or where an agreement to use other values has not been made between the purchaser and vendor.

NOTE II: These values are applicable only to low carbon, non-alloy steels. For other materials, the values shall be a matter of agreement between the purchaser and vendor.

NOTE III: The test results specified are not likely to be attained with the metal arc process when using bare or lightly coated electrodes. For such processes it is recommended that the governing Code adopt the following requirements for the test results:

a. Reduced-Section Tension Test—The tensile strength shall be not less than 85 per cent of the minimum of the specified tensile range of the base material used.

b. Free-Bend Test—The elongation shall be not less than 10 per cent.

c. Root-, Face-, Side-Bend and Fillet-Weld-Soundness Tests—The specimen shall be considered as having passed if (1) no crack or other open defect exceeding $^1/_8$ in. measured in any direction is present in the weld metal or between the weld and base material after the bending, or (2) the specimen has cracked or fractured and the fractured surface shows complete penetration through the entire thickness of the weld, and absence of slag inclusions and porosity to the extent that there are no gas pockets or slag inclusions exceeding $^1/_{16}$ in. in greatest dimension and the sum of the greatest dimension of all such defects in any square inch of weld metal area does not exceed $^3/_8$ in. (If necessary, the specimen shall be broken apart to permit examination of the fracture.)

d. Longitudinal or Transverse Shear Test—For the longitudinal shear test specimen the shearing strength of the welds in pounds per square inch shall be not less than $^2/_3$ of the minimum of the specified tensile range of the base material. For the transverse shear test specimen the shearing strength of the welds in pounds per sq. in. shall be not less than $^7/_8$ of the minimum of the specified tensile range of the base material.

110. Records

Records of the test results shall be kept by the manufacturer or contractor and shall be available to those authorized to examine them.

PART II—OPERATOR QUALIFICATION

204. Position of Test Welds

The requirements for the test results shall be as follows:

tractor and shall be available to those authorized to examine them.

PART II—OPERATOR QUALIFICATION

201. Limitation of Variables

For the qualification of an operator the following rules shall apply. If certain changes are made in a Procedure Specification, operator requalification may be required in accordance with Article 101 (*b*).

202. Types of Tests Required

The qualification tests described herein are specially devised tests to determine the operator's ability to produce sound welds, and may or may not conform in every detail to the requirements of the Procedure Specification. It is not intended that the practices required in the qualification tests shall be used as a guide for welding during actual construction. The latter shall be performed in accordance with the requirements of the Procedure Specification.

The tests used for operator qualification are as follows:

(*a*) *For Groove Welds*

(1) Root-Bend Test
(2) Face-Bend Test
(3) Side-Bend Test

(*b*) *For Fillet Welds*

Fillet-Weld-Soundness Test

203. Base Material and Its Preparation

(*a*) The base material shall comply with the specification for one of the materials listed in the Procedure Specification. For all types of welded joints the length of the weld and the dimensions of the base material shall be such as to provide sufficient material for the test specimens called for hereinafter.

(*b*) For groove welds in plate or pipe where the thickness of the material for the tests as specified in Article 205 (*a*) is $^3/_8$ in., the preparation of the base material for welding shall be for a single-V groove butt joint meeting the requirements of Fig. 22, except that in the case of oxyacetylene welding the joint preparation may be in accordance with Fig. 24.

(*c*) For groove welds in plate or pipe where the thickness of the material as specified in Article 205 (*a*) exceeds $^3/_8$ in., the preparation of the base material for welding shall be for a single-V groove butt joint meeting the requirements of Fig. 23, except that in the case of oxyacetylene welding the joint preparation may be in accordance with Fig. 25.

(*d*) For fillet welds the preparation of the base material for welding shall be as shown in Fig. 26. Pipe with a nominal diameter of not less than 6 in. may be used in lieu of plate.

204. Position of Test Welds

(*a*) *Groove Welds*

For the purpose of determining the ability of an operator to make groove welds in various positions in plate or pipe the following positions for test are required.

Test Position 1G

Plates placed in an approximately horizontal plane and the weld metal deposited from the upper side, or a pipe placed with its axis in an approximately horizontal plane with the welding groove in an approximately vertical plane, the pipe being rolled while the weld is deposited within the top quadrant and from the outside of the pipe. (See Fig. 21 (*a*).) This test made either in plate or pipe will qualify the operator for flat position welds in plate and for pipe in the horizontal rolled position. (See Fig. 1 (*a*).)

Test Position 2G

Plates placed in an approximately vertical plane with the welding groove in an approximately horizontal plane, or a pipe placed with its axis in an approximately vertical plane with the welding groove in an approximately horizontal plane. (See Fig. 21 (*b*).) This test made either in plate or pipe will qualify the operator for flat and horizontal welds in plate and for pipe in the horizontal rolled and vertical fixed positions. (See Fig. 1 (*a*).)

Test Position 3G

Plates placed in an approximately vertical plane with the welding groove approximately vertical. (See Fig. 21 (*c*).) This test will qualify the operator for flat and vertical welds in plate and for pipe in the horizontal rolled position. (See Fig. 1 (*a*).)

Test Position 4G

Plates placed in an approximately horizontal plane and the weld metal deposited from the under side. (See Fig. 21 (*d*).) This test will qualify the operator for flat, and overhead welds in plate and for pipe in the horizontal rolled position.

Test Position 5G

A pipe or plate box placed with its axis in an approximately horizontal plane with the welding groove in an approximately vertical plane. The pipe or box shall not be rolled or turned during welding, thus requiring the operator to deposit weld metal from the flat, vertical and overhead positions. (See Fig. 21 (*e*).) This test made either in pipe or a plate box will qualify the operator for welds made in plate in the flat, vertical and overhead positions, and in pipe in the horizontal rolled and horizontal fixed positions. (See Fig. 1 (*a*).)

If a welding operator is tested in Position 2G he need not be tested in Position 1G. If a welding operator is tested in Position 3G he need not be tested in Position 1G. If a welding operator is tested in Position 4G he need not be tested in Position 1G. If a welding operator is tested in Position 5G he need not be tested in Position 1G, 3G or 4G.

(*b*) *Fillet Welds*

For the purpose of determining the ability of an operator to make fillet welds in various positions the following positions for test are required:

Test Position 1F

Plates placed in such position that each weld is deposited with its axis approximately horizontal and with its throat approximately vertical. (See Fig. 27 (*a*).) This test will qualify the operator for flat fillet welds. (See Fig. 1 (*b*).)

Test Position 2F

Plates or pipe placed in such position that each weld is deposited on the upper side of the horizontal surface and against the vertical surface. (See Fig. 27 (*b*).) This test, made either in plate or pipe, will qualify the operator for flat and horizontal fillet welds. (See Fig. 1 (*b*).)

Test Position 3F

Plates or pipe placed in such position that each weld is made vertically. (See Fig. 27 (*c*).) This test, made either in plate or pipe, will qualify the operator for flat, horizontal and vertical fillet welds. (See Fig. 1 (*b*).)

Test Position 4F

Plates or pipe placed in such position that each weld is deposited on the under side of the horizontal surface and against the vertical surface. (See Fig. 27 (*d*).) This test, made either in plate or pipe, will qualify the operator for flat, horizontal and overhead fillet welds. (See Fig. 1 (*b*).)

NOTE: The above arrangement of test plates or pipe refers only to the making of the fillet weld. The closing weld between fillet welds in the fillet-weld-soundness test may be made in any position. See Fig. 27 (*e*).

If a welding operator is tested in Position 2F he need not be tested in Position 1F. If a welding operator is tested in Position 3F he need not be tested in Position 1F or 2F. If a welding operator is tested in Position 4F he need not be tested in Position 1F or 2F.

205. Number of Test Welds Required

(*a*) *Groove Welds in Plate and Pipe*

For groove welds in material up to and including $^3/_4$ in. thick* one test weld as shown in Fig. 22 (Fig. 24 may be used for oxyacetylene welding) shall be made in material $^3/_8$ in. thick for each position for which the operator is to be qualified as defined by Article 204 (*a*), except that if the construction involves welding of material over $^3/_4$ in. thick* one test weld as shown in Fig. 23 (Fig. 25 may be used for oxyacetylene welding) shall be made for each such position in material of the maximum thickness to be used in construction, but the thickness of the material for the test weld need not exceed 1 in. If a test weld is made in the maximum or 1-in. thickness, no test weld need be made in the $^3/_8$-in. thickness. In the case of pipe, the nominal diameter of the pipe used for the test weld shall not be less than 6 in.

(*b*) *Fillet Welds*

a. For fillet welds one test weld as shown in Fig. 26 shall be made for each position for which the operator is to be qualified, as defined by Article 204 (*c*).

206. Welding Procedure

The operator shall follow the welding procedure specified by the Procedure Specification except that if the form of the test joint differs from the forms of joint as shown in the Procedure Specification to such a degree that it is necessary, in welding the test joint, to change the electrode or welding rod diameters or the number and arrangement of passes from that called for in the Procedure Specification, such changes shall be permissible.

207. Test Specimens—Number, Type and Preparation

(*a*) *Groove Welds*

For groove welds in plate the method of preparing the specimens shall be in accordance with the figures referred to in Table 3 and the number of tests required shall be as given in the table.

For groove welds in pipe the method of preparing the specimens shall be in accordance with the figures referred to in Table 4 and the number of tests required shall be as given in the table.

If the test weld is made in pipe in Position 1G or 2G, the specimens shall be removed approximately 90° from each other. If the test weld is made in Position 5G, using either a pipe or a plate box, a specimen shall be removed from the top, the bottom and each of the two sides of the test weld; and, if the weld is made in $^3/_8$-in.-thick material, the specimen from the top and one side shall be tested with the face of the weld in tension, and the specimen from the bottom and from the other side shall be tested with the root of the weld in tension.

(*b*) *Fillet Welds*

Two test specimens shall be removed from each test weld and prepared for testing as shown in Fig. 20.

208. Method of Testing Specimens

(*a*) *Root-, Face-, Side-Bend and Fillet-Weld-Soundness Specimens*

Each specimen shall be bent in a jig substantially in accordance with Fig. 19. Any convenient means may be used for moving the male member with relation to the female member.

The specimen shall be placed on the female member of the jig with the weld at midspan. Face-bend specimens shall be placed with the face of the weld directed toward the gap; root-bend and fillet-weld-soundness specimens shall be placed with the root of the weld directed toward the gap; side-bend specimens shall be placed with that side showing the greater defects, if any, directed toward the gap. The two members of the jig shall be forced together until the curvature of the specimen is such that a $^1/_{32}$-

* Whereas reference has been made above to the test welds being made in material of a given thickness, it is the intent of these rules that if an operator is qualified to weld in a single groove of a given depth, he is also considered as being qualified for welding double-groove butt joints wherein the depth of the groove from either side does not exceed the depth of the single groove for which he has been qualified.

double-groove butt joints wherein the depth of the groove from either side does not exceed the depth of the single groove for which he has been qualified.

defects, if any, directed toward the gap. The two members of the jig shall be forced together until the curvature of the specimen is such that a $^1/_{32}$-

TABLE 3—OPERATOR QUALIFICATION TESTS FOR GROOVE WELDS IN PLATE

Maximum Thickness for Which Operator Is to Be Qualified	Thickness of Material for Test Weld	Number and Type of Tests Required		
		Root-Bend. (See Fig. 8)	Face-Bend. (See Fig. 8)	Side-Bend. (See Fig. 9)
Up to and including $^3/_4$ in.	$^3/_8$ in.	1	1	..
Over $^3/_4$ in.	Maximum, but need not exceed 1 in.	..	..	2

TABLE 4—OPERATOR QUALIFICATION TESTS FOR GROOVE WELDS IN PIPE

Maximum Thickness for Which Operator Is to Be Qualified	Thickness of Material for Test Weld	Number and Type of Tests Required		
		Root-Bend. (See Fig. 14)	Face-Bend. (See Fig. 14)	Side-Bend. (See Fig. 9)
Up to and including $^3/_4$ in.	$^3/_8$ in.	2	2	..
Over $^3/_4$ in.	Maximum, but need not exceed 1 in.	..	..	4

in. diameter wire cannot be passed between the curved portion of the male member and the specimen. The specimen shall then be removed from the jig.

209. Test Results Required

(*a*) *Root-, Face-, Side-Bend and Fillet-Weld-Soundness Tests*

The convex surface of the specimen shall be examined for the appearance of cracks or other open defects. Any specimen in which a crack or other open defect is present after the bending, exceeding $^1/_8$ in. measured in any direction, shall be considered as having failed. Cracks occurring on the corners of the specimen during testing shall not be considered. (See Notes I and II.)

NOTE I: These values as set forth shall apply where no Code is in effect, or where an agreement to use other values has not been made between the purchaser and vendor.

NOTE II: The test results specified are not likely to be attained with the metal arc process when using bare or lightly coated electrodes. For such processes it is recommended that the governing Code adopt the following requirements for the test results:

The specimen shall be considered as having passed if (1) no crack or other open defect exceeding $^1/_8$ in. measured in any direction is present in the weld metal or between the weld and base material after the bending, or (2) the specimen has cracked or fractured and the fractured surface shows complete penetration through the entire thickness of the weld, and absence of slag inclusions and porosity to the extent that there are no gas pockets or slag inclusions exceeding $^1/_{16}$ in. in greatest dimension and the sum of the greatest dimension of all such defects in any square inch of weld metal area does not exceed $^3/_8$ in. (If necessary, the specimen shall be broken apart to permit examination of the fracture.)

210. Retests

In case an operator fails to meet the requirements of one or more test welds a retest may be allowed under the following conditions:

(*a*) An immediate retest may be made which shall consist of two test welds of each type on which he failed, all of which shall meet all the requirements specified for such welds.

(*b*) A retest may be made provided there is evidence that the operator has had further training or practice. In this case a complete retest shall be made.

211. Period of Effectiveness

The operator qualification tests herein specified shall be considered as remaining in effect indefinitely unless (1) the welding operator is not engaged in a given process of welding (i.e., arc or gas) for a period of three months or more;* or unless (2) there is some specific reason to question an operator's ability. In case (1) above the requalification test need be made only in the $^3/_8$ in. thickness.

212. Records

Copies of the record for each qualified welding operator shall be kept by the manufacturer or contractor, and shall be available to those authorized to examine them.

* The intent of this statement is as follows:

An operator who has been qualified for metal arc welding under any given Procedure Specification is not required to requalify for that Procedure unless he has done no metal arc welding for a period of three months or more. In a similar manner the qualification of an operator for gas welding or for carbon arc welding is not considered as having expired unless he has done no gas welding or carbon arc welding, as the case may be, for a period of three months or more.

TABLE 5—GROUPING OF MATERIALS FOR PROCEDURE AND OPERATOR QUALIFICATION*

"P" Number 1—"O" Number 1

Materials in this group shall not have a carbon content exceeding 0.30 per cent, a manganese content exceeding 1.10 per cent, or a silicon content exceeding 0.50 per cent, as determined by ladle analysis. In addition, the carbon content by percentage shall not exceed the value $0.55 - \left(\frac{Mn + Si}{4}\right)$, where Mn is the percentage of manganese and Si is the percentage of silicon.

A. S. T. M. Spec. No.	Name
A-7	Steel for Bridges and Buildings
A-10	Mild Steel Plates
A-30	Boiler and Firebox Steel for Locomotives
A-53	Welded and Seamless Steel Pipe
A-70	Carbon-Steel Plates for Stationary Boilers, etc.
A-78	Low Tensile Strength Carbon Steel Plates of Structural Quality for Welding
A-83	Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes

* Steels not included in the table require separate procedure and operator qualification except in the case of the so-called low-alloy, high-strength steels. In the latter group of steels separate procedure qualification is required for each change in brand or analysis but "O" Number 1 applies in all cases.

"P" Number 1—"O" Number 1—(*Continued*)

A-87	Grade A1	Carbon-Steel and Alloy-Steel Castings for Railroads
	Grade A2	Carbon-Steel and Alloy-Steel Castings for Railroads
A-89		Low Tensile Strength Carbon-Steel Plates of Flange and Firebox Quality
A-105		Forged or Rolled Steel Pipe Flanges for High-Temperature Service
A-106	Grade A	Lap-Welded and Seamless Steel Pipe for High-Temperature Service
	Grade OH	Lap-Welded and Seamless Steel Pipe for High-Temperature Service
A-107	Grade 1	Commercial Quality Hot-Rolled Bar Steels
	Grade 2	Commercial Quality Hot-Rolled Bar Steels
	Grade 3	Commercial Quality Hot-Rolled Bar Steels
	Grade 4	Commercial Quality Hot-Rolled Bar Steels
	Grade 5	Commercial Quality Hot-Rolled Bar Steels
	Grade 17	Commercial Quality Hot-Rolled Bar Steels
A-113		Structural Steel for Locomotives and Cars
A-120		Black Welded and Seamless Steel Pipe, etc. (Galvanized pipe not included)
A-129		Open-Hearth Iron Plates of Flange Quality
A-131		Structural Steel for Ships
A-134		Electric-Fusion-Welded Steel Pipe (Size 30 in. and over)
A-135		Electric-Resistance-Welded Steel Pipe
A-136		Forge-Welded Steel Pipe
A-139		Electric-Fusion-Welded Steel Pipe (8 in. to but not including 30 in. diam.)
A-155		Electric-Fusion-Welded Steel Pipe for High-Temperature and High-Pressure Service
A-178	Grade A	Electric-Resistance-Welded Steel and Open-Hearth Iron Boiler Tubes
	Grade B	Electric-Resistance-Welded Steel and Open-Hearth Iron Boiler Tubes
A-181		Forged or Rolled Steel Pipe Flanges for General Service
A-192		Seamless Steel Boiler Tubes for High-Pressure Service
A-201		Carbon-Silicon Steel Plates of Ordinary Tensile Ranges
A-215-39T	Grade N-1-W	Carbon-Steel Castings Suitable for Fusion Welding, etc.
	Grade A-1-W	Carbon-Steel Castings Suitable for Fusion Welding, etc.
	Grade A-2-W	Carbon-Steel Castings Suitable for Fusion Welding, etc.
	Grade A-3-W	Carbon-Steel Castings Suitable for Fusion Welding, etc.
A-216-40T	Grade WCA	Carbon Steel Castings Suitable for Fusion Welding, etc. (to 850° F.)
A-235-40T	Grade A	Carbon-Steel Forgings for General Industrial Use
	Grade B	Carbon-Steel Forgings for General Industrial Use
	Grade C	Carbon-Steel Forgings for General Industrial Use
A-236-40T	Grade A	Carbon-Steel Forgings for Locomotives and Cars

"P" Number 2—"O" Number 1

A-42	Wrought-Iron Plates
A-72	Welded Wrought-Iron Pipe
A-73	Wrought-Iron Rolled or Forged Blooms and Forgings
A-162	Uncoated Wrought-Iron Sheets
A-207	Rolled Wrought-Iron Shapes and Bars

"P" Number 3—"O" Number 1

Materials in this group shall not have a carbon content exceeding 0.35 per cent, a manganese content exceeding 1.50 per cent, or a silicon content exceeding 0.50 per cent, as determined by ladle analysis. In addition, the carbon content by percentage shall not exceed the value $0.65 - \left(\frac{Mn + Si}{4}\right)$, where Mn is the percentage of manganese and Si is the percentage of silicon.

(Experience has indicated that it is advisable to preheat up to 350° F. when welding the materials included in this group.)

A-7		Steel for Bridges and Buildings
A-30		Boiler and Firebox Steel for Locomotives
A-70		Carbon-Steel Plates for Stationary Boilers, etc.
A-87	Grade B	Carbon-Steel and Alloy-Steel Castings for Railroads
A-95		Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service
A-105		Forged or Rolled Steel Pipe Flanges for High-Temperature Service
A-106	Grade B	Lap-Welded and Seamless Steel Pipe for High-Temperature Service
A-107	Grade 6	Commercial Quality Hot-Rolled Bar Steels
	Grade 7	Commercial Quality Hot-Rolled Bar Steels
A 31		Structural Steel for Ships
A-178	Grade C	Electric-Resistance-Welded Steel and Open-Hearth Iron Boiler Tubes
A-181		Forged and Rolled Steel Pipe Flanges for General Service
A-201		Carbon-Silicon Steel Plates of Ordinary Tensile Ranges, etc.
A-210		Medium-Carbon Seamless Steel Boiler and Superheater Tubes
A-212		High-Tensile Strength Carbon-Silicon Steel Plates, etc.
A-215-39T	Grade N-2-W	Carbon-Steel Castings Suitable for Fusion Welding, etc.
	Grade BW	Carbon-Steel Castings Suitable for Fusion Welding, etc.
	Grade B-1-W	Carbon-Steel Castings Suitable for Fusion Welding, etc.
	Grade B-2-W	Carbon-Steel Castings Suitable for Fusion Welding, etc.
A-216-40T	Grade WCB	Carbon-Steel Castings Suitable for Fusion Welding, etc. (to 850° F.)
A-235-40T	Grade C1	Carbon-Steel Forgings for General Industrial Use
	Grade D	Carbon-Steel Forgings for General Industrial Use
	Grade E	Carbon-Steel Forgings for General Industrial Use
A-236-40T	Grade B	Carbon-Steel Forgings for Locomotives and Cars
	Grade C	Carbon-Steel Forgings for Locomotives and Cars
	Grade D	Carbon-Steel Forgings for Locomotives and Cars

"P" Number 4—"O" Number 1

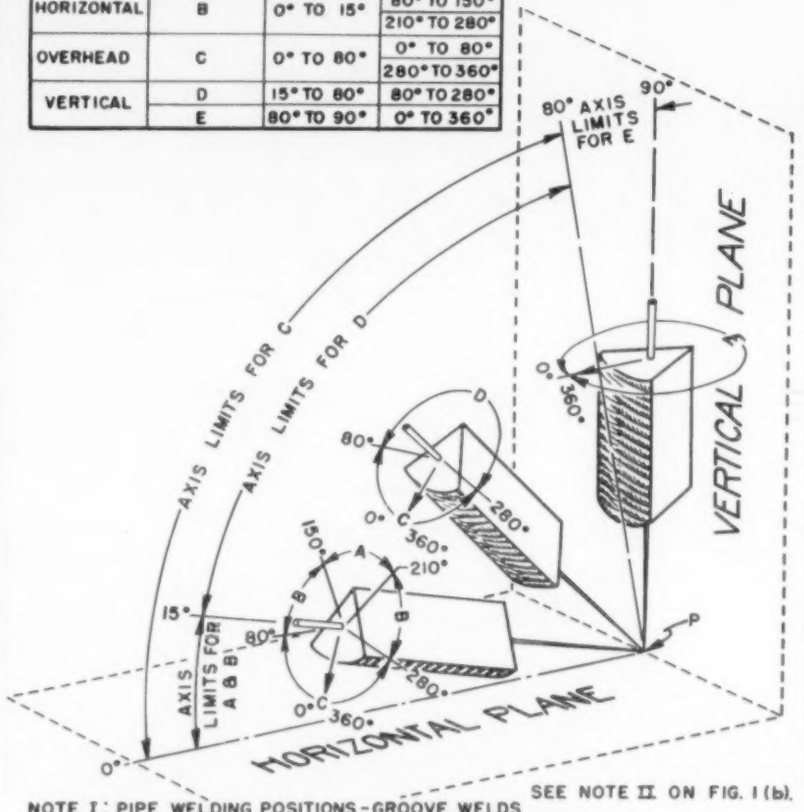
The carbon content by ladle analysis shall not exceed 0.28 per cent.

A-182	Grade F1	Forged or Rolled Alloy-Steel Pipe Flanges, etc. (from 750–1100° F.)
A-202	Grade A	Cr-Mn-Si Alloy-Steel Plates for Boilers, etc.
A-203	Grade A	Low-Carbon Nickel-Steel Plates for Boilers, etc.
	Grade B	Low-Carbon Nickel-Steel Plates for Boilers, etc.
A-204	Grade A	Molybdenum-Steel Plates for Boilers, etc.
	Grade B	Molybdenum-Steel Plates for Boilers, etc.
	Grade C	Molybdenum-Steel Plates for Boilers, etc.
A-206-40T		Seamless Carbon-Molybdenum Alloy-Steel Pipe for Service at Temperatures of 750–1000° F.
A-209-40T		Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes
A-217	Grade WC1	Alloy-Steel Castings Suitable for Fusion Welding, etc. (750–1100° F.)
	Grade WC2	Alloy-Steel Castings Suitable for Fusion Welding, etc. (750–1100° F.)
A-225		Manganese-Vanadium Steel Plates for Boilers, etc.

and Si is the percentage of silicon.

TABULATION OF POSITIONS OF GROOVE WELDS

POSITION	DIAGRAM REFERENCE	INCLINATION OF AXIS	ROTATION OF FACE
FLAT	A	0° TO 15°	150° TO 210°
HORIZONTAL	B	0° TO 15°	80° TO 150°
			210° TO 280°
OVERHEAD	C	0° TO 80°	0° TO 80°
			280° TO 360°
VERTICAL	D	15° TO 80°	80° TO 280°
	E	80° TO 90°	0° TO 360°



SEE NOTE II ON FIG. 1 (b).

NOTE I: PIPE WELDING POSITIONS-GROOVE WELDS

FOR GROOVE WELDS IN PIPE THE FOLLOWING DEFINITIONS SHALL APPLY.

HORIZONTAL FIXED POSITION: WHEN THE AXIS OF THE PIPE DOES NOT DEVIATE BY MORE THAN 30° FROM THE HORIZONTAL PLANE AND THE PIPE IS NOT ROTATED DURING WELDING.

HORIZONTAL ROLLED POSITION: WHEN THE AXIS OF THE PIPE DOES NOT DEVIATE BY MORE THAN 30° FROM THE HORIZONTAL PLANE, THE PIPE IS ROTATED DURING WELDING, AND THE WELD METAL IS DEPOSITED WITHIN AN ARC NOT TO EXCEED 15° ON EITHER SIDE OF A VERTICAL PLANE PASSING THROUGH THE AXIS OF THE PIPE.

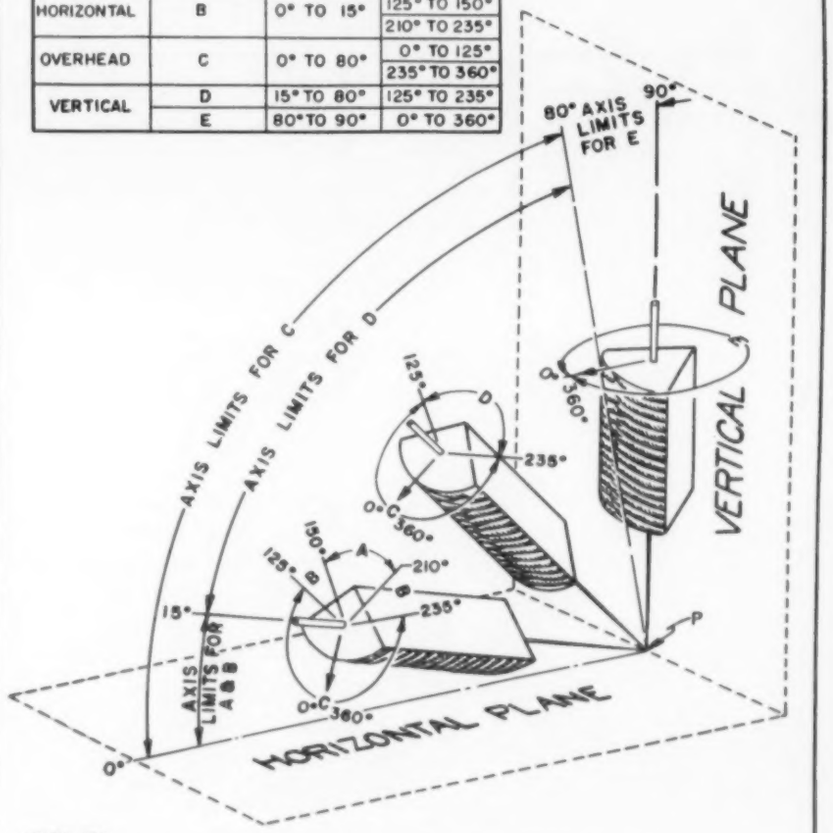
VERTICAL POSITION: WHEN THE AXIS OF THE PIPE DOES NOT DEVIATE BY MORE THAN 10° FROM THE VERTICAL POSITION (THE PIPE MAY OR MAY NOT BE ROTATED DURING WELDING.)⊕

⊕POSITIONS IN WHICH THE AXIS OF THE PIPE DEVIATES BY MORE THAN 10° AND LESS THAN 60° FROM THE VERTICAL SHALL BE CONSIDERED INTERMEDIATE, AND SHALL REQUIRE THE PROCEDURE AND OPERATOR TO BE QUALIFIED IN BOTH THE HORIZONTAL FIXED AND THE VERTICAL POSITIONS.

POSITIONS OF GROOVE WELDS
FIGURE 1 (a)

TABULATION OF POSITIONS OF FILLET WELDS

POSITION	DIAGRAM REFERENCE	INCLINATION OF AXIS	ROTATION OF FACE
FLAT	A	0° TO 15°	150° TO 210°
HORIZONTAL	B	0° TO 15°	125° TO 150°
			210° TO 235°
OVERHEAD	C	0° TO 80°	0° TO 125°
			235° TO 360°
VERTICAL	D	15° TO 80°	125° TO 235°
	E	80° TO 90°	0° TO 360°



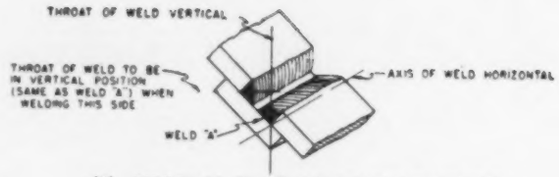
NOTE II:

THE HORIZONTAL REFERENCE PLANE IS TAKEN TO LIE ALWAYS BELOW THE WELD UNDER CONSIDERATION.

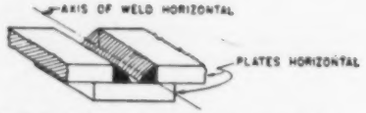
INCLINATION OF AXIS IS MEASURED FROM THE HORIZONTAL REFERENCE PLANE TOWARD THE VERTICAL.

ANGLE OF ROTATION OF FACE IS MEASURED FROM A LINE PERPENDICULAR TO THE AXIS OF THE WELD AND LYING IN A VERTICAL PLANE CONTAINING THIS AXIS. THE REFERENCE POSITION (0°) OF ROTATION OF THE FACE INVARIABLY POINTS IN THE DIRECTION OPPOSITE TO THAT IN WHICH THE AXIS ANGLE INCREASES. THE ANGLE OF ROTATION OF THE FACE OF WELD IS MEASURED IN A CLOCKWISE DIRECTION FROM THIS REFERENCE POSITION (0°) WHEN LOOKING AT POINT P.

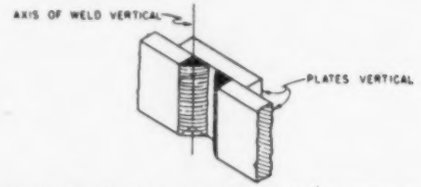
POSITIONS OF FILLET WELDS
FIGURE 1 (b)


THROAT OF WELD VERTICAL
THROAT OF WELD TO BE IN VERTICAL POSITION (SAME AS WELD 'A') WHEN WELDING THIS SIDE
AXIS OF WELD HORIZONTAL
WELD 'A'

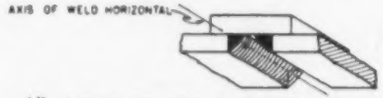
(a) POSITION OF TEST PLATES FOR FLAT FILLET WELD



(b) POSITION OF TEST PLATES FOR HORIZONTAL FILLET WELD

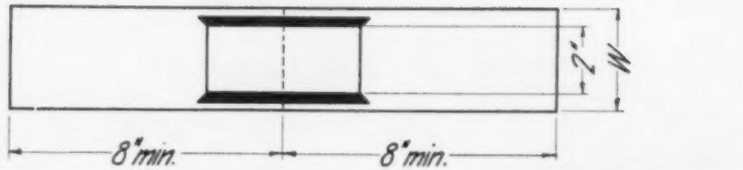


(c) POSITION OF TEST PLATES FOR VERTICAL FILLET WELD



(d) POSITION OF TEST PLATES FOR OVERHEAD FILLET WELD

Fig. 2—Positions of Test Plates for Fillet Welds



Dimensions

Size of weld F, in.	⅛	¼	⅜	½
Thickness t, in., min.	⅜	½	¾	1
Thickness T, in.	⅜	¾	1	1¼
Width W, in.	3	3	3	3½

Fig. 3—Longitudinal Fillet-Weld Shearing Specimen After Welding

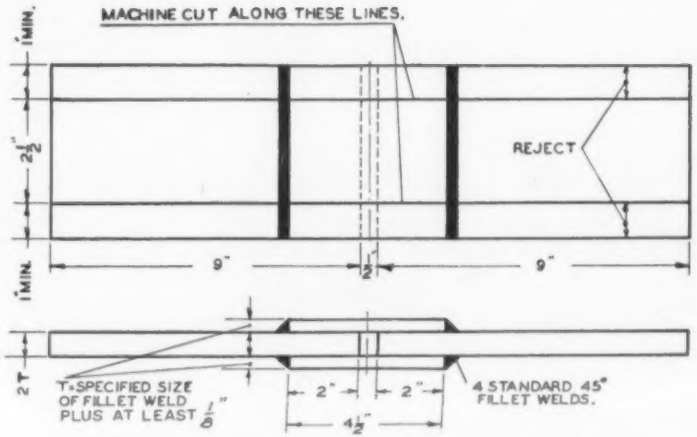


Fig. 4—Transverse Fillet-Weld Shearing Specimen

Weld reinforcement

Fig. 4—Transverse Fillet-Weld Shearing Specimen

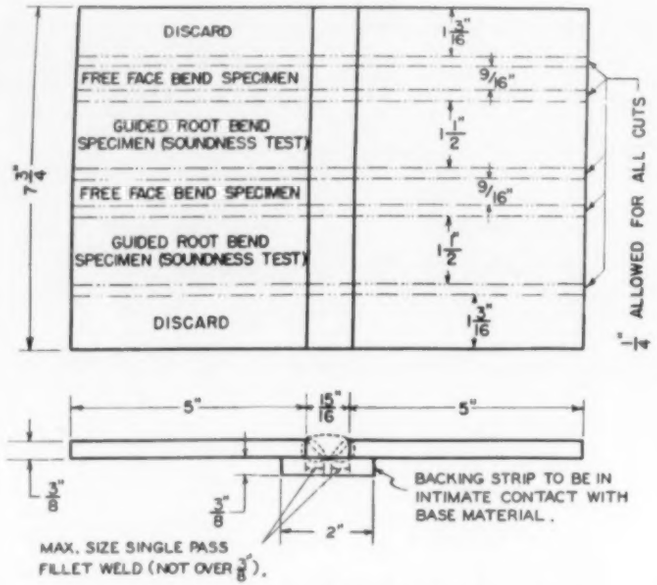


Fig. 5—Test Weld for Free-Bend and Soundness Tests

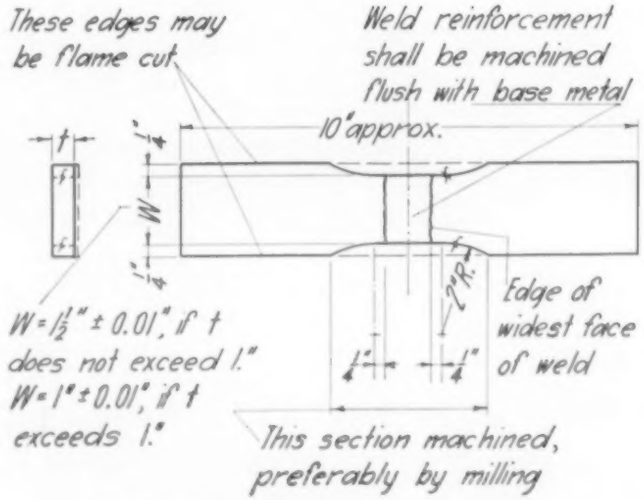
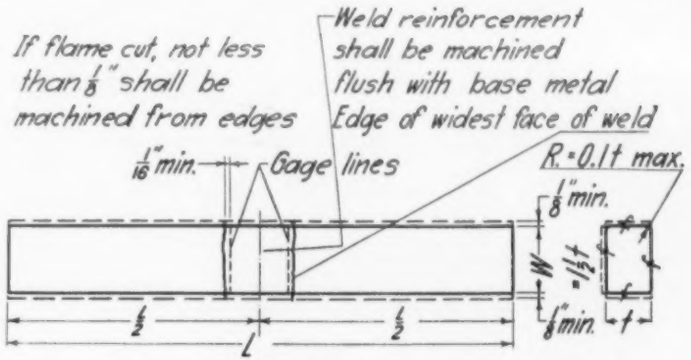

These edges may be flame cut
Weld reinforcement shall be machined flush with base metal
10" approx.
W = 1 1/2" ± 0.01" if t does not exceed 1"
W = 1" ± 0.01" if t exceeds 1"
2" R.
Edge of widest face of weld
This section machined, preferably by milling

Fig. 6—Reduced-Section Tension Specimen (Plate)



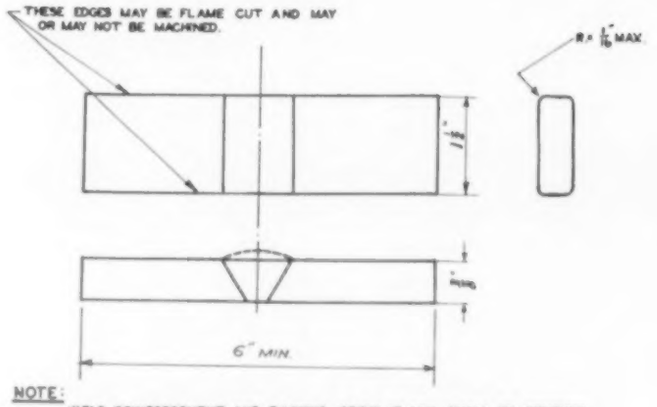
Dimensions

t, in.	3/8	3/4	1	1 1/4	1 1/2	2	2 1/2
W, in.	9/16	1 1/8	1 1/2	1 7/8	2 1/4	3	3 3/4
L min, in.	8	11	12	13 1/2	15	18	21
B* min, in.	1 1/4	2	2	2	2	2	3

*See fig. 18

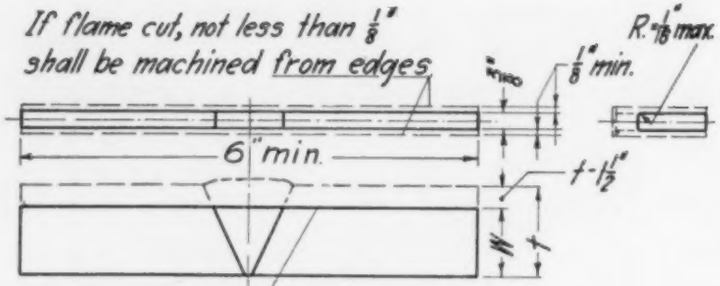
Note:- the length L is suggestive only, not mandatory

Fig. 7—Free-Bend Specimen (Plate)



NOTE: WELD REINFORCEMENT AND BACKING STRIP, IF ANY, SHALL BE REMOVED FLUSH WITH THE SURFACE OF THE SPECIMEN. IF A RECESSED STRIP IS USED THIS SURFACE OF THE SPECIMEN MAY BE MACHINED TO A DEPTH NOT EXCEEDING THE DEPTH OF THE RECESS TO REMOVE THE STRIP, EXCEPT THAT IN SUCH CASES THE THICKNESS OF THE FINISHED SPECIMEN SHALL BE THAT SPECIFIED ABOVE.

Fig. 8—Face- and Root-Bend Specimens (Plate)


If flame cut, not less than 1/8" shall be machined from edges
R. 1/16" max.
1/8" min.
6" min.
t - 1 1/2"
t
Cut along this line when t exceeds 1 1/2"; edge may be flame cut and may or may or may not be machined

t, in.	W, in.
3/4" to 1 1/2"	t
> 1 1/2"	1 1/2"

Fig. 9—Side-Bend Specimen

Discard		This Piece
Side Bend		Specimen
Reduced Section		Tensile Specimen
Side Bend		Specimen
Free Bend		Specimen
Side Bend		Specimen
Reduced Section		Tensile Specimen
Side Bend		Specimen
Free Bend		Specimen
Discard		This Piece

Fig. 10—Order of Removal of Test Specimens from Welded Test Plate (for Plate Over 3/4 In. Thick)

Discard		This Piece
Reduced Section		Tensile Specimen
Root Bend		Specimen
Free Bend		Specimen
Face Bend		Specimen
Root Bend		Specimen
Free Bend		Specimen
Face Bend		Specimen
Reduced Section		Tensile Specimen
Discard		This Piece

Fig. 11—Order of Removal of Test Specimens from Welded Test Plate (for Plate 3/8 In. Thick)

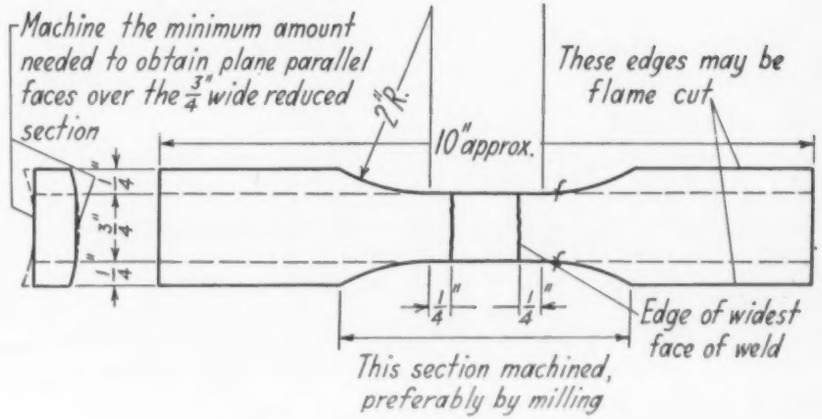


Fig. 12—Reduced Section Tension Specimen (Pipe)

Fig. 12—Reduced Section Tension Specimen (Pipe)

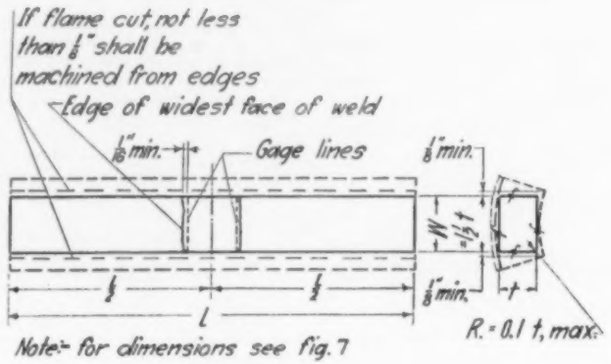
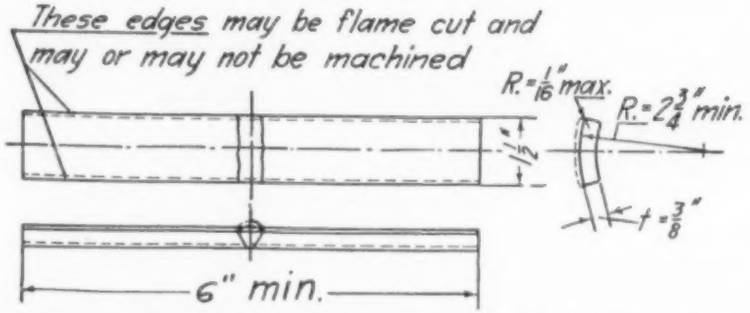

If flame cut, not less than 1/8" shall be machined from edges
Edge of widest face of weld
1/8" min.
Gage lines
1/8" min.
W = 1 1/2 t
1/8" min.
t
L
R. = 0.1 t, max.
Note:- for dimensions see fig. 7

Fig. 13—Free-Bend Specimen (Pipe)



NOTE. Weld reinforcement and backing ring, if any, shall be removed flush with the surface of the specimen. If a recessed ring is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the ring, except that in such cases the thickness of the finished specimen shall be that specified above.

Fig. 14—Face- and Root-Bend Specimens (Pipe)

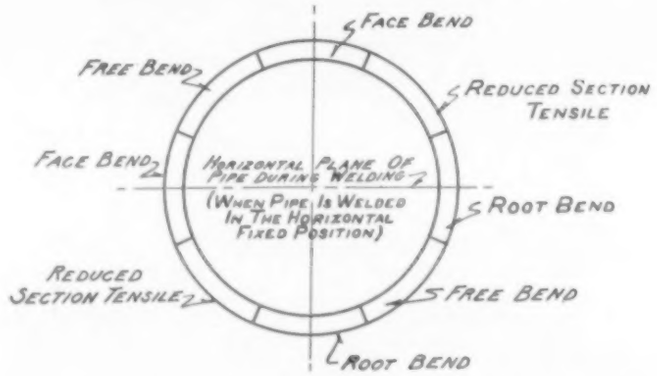


Fig. 15—Order of Removal of Test Specimens from Welded Pipe (for Pipe 3/8 In. Thick)

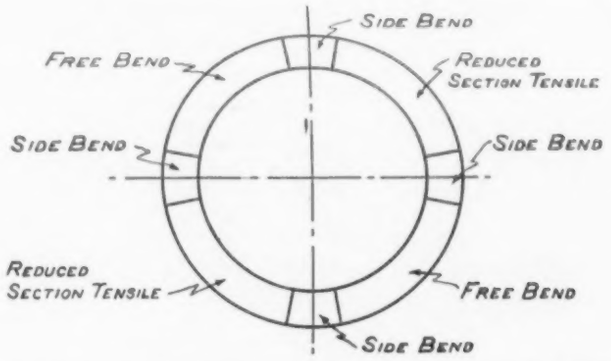


Fig. 16—Order of Removal of Test Specimens from Welded Pipe (for Pipe Over Thick)

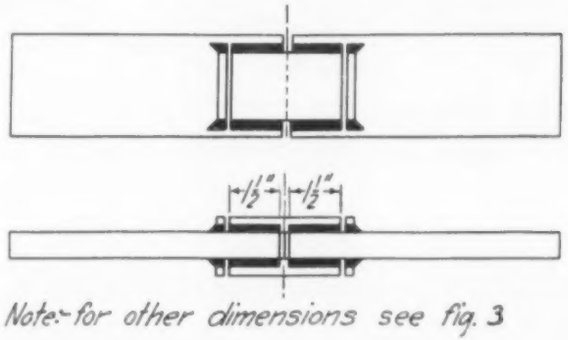


Fig. 17—Longitudinal Fillet-Weld Shearing Specimen After Machining

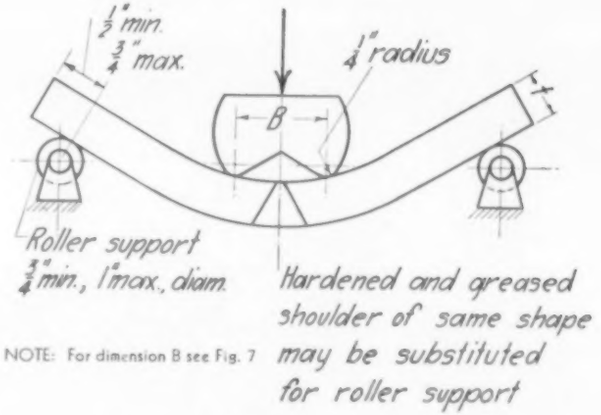


Fig. 18—Initial Bend for Free-Bend Specimens

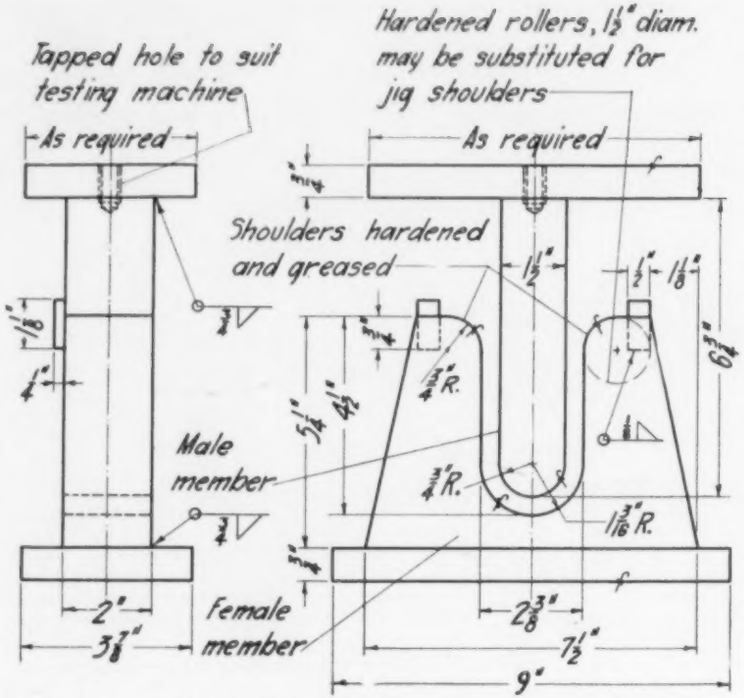


Fig. 19—Guided-Bend Test Jig

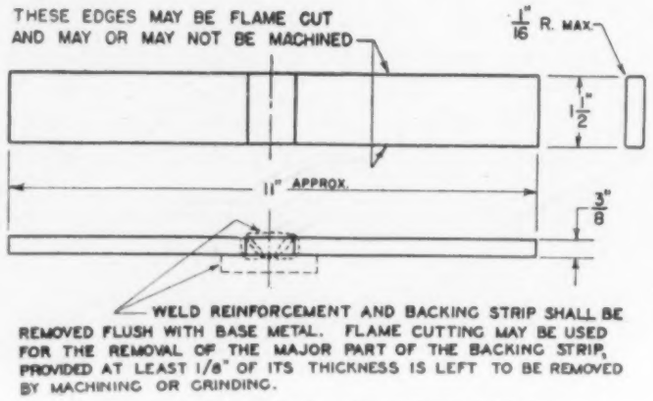
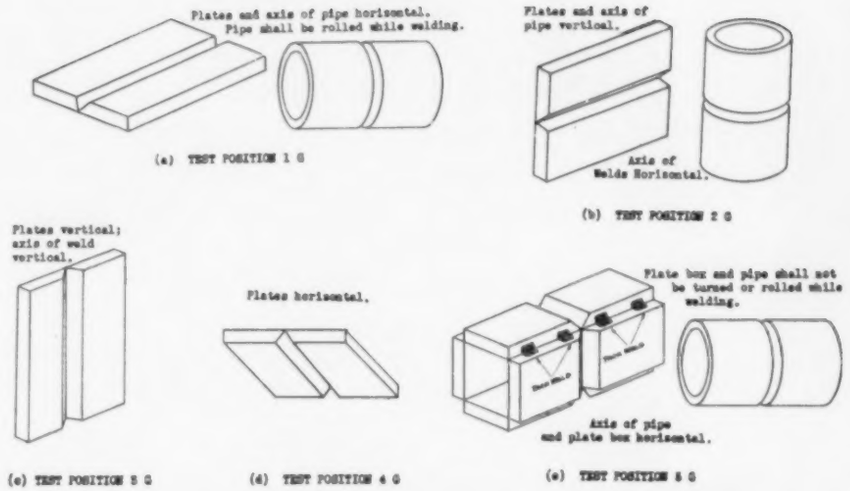

THESE EDGES MAY BE FLAME CUT AND MAY OR MAY NOT BE MACHINED
1/16" R. MAX.
1½"
11" APPROX.
⅜"
WELD REINFORCEMENT AND BACKING STRIP SHALL BE REMOVED FLUSH WITH BASE METAL. FLAME CUTTING MAY BE USED FOR THE REMOVAL OF THE MAJOR PART OF THE BACKING STRIP, PROVIDED AT LEAST 1/8" OF ITS THICKNESS IS LEFT TO BE REMOVED BY MACHINING OR GRINDING.

Fig. 20—Fillet-Weld-Soundness Test Specimen


Plates and axis of pipe horizontal. Pipe shall be rolled while welding.
(a) TEST POSITION 1 G
Plates and axis of pipe vertical.
Axis of Welds Horizontal.
(b) TEST POSITION 2 G
Plates vertical; axis of weld vertical.
(c) TEST POSITION 3 G
Plates horizontal.
(d) TEST POSITION 4 G
Plate box and pipe shall not be turned or rolled while welding.
Axis of pipe and plate box horizontal.
(e) TEST POSITION 5 G

NOTE: For procedure qualification the type of groove shall comply with the Procedure Specification, for operator qualification the shape of the groove and backing strip shall be as shown in Figs. 22, 23, 24 and 25.

Fig. 21—Positions of Test Plates or Pipe for Groove Welds

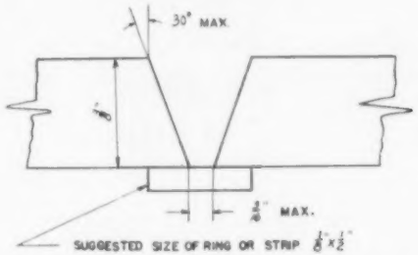


Fig. 22—Butt Joint for Operator Qualification, for Plate or Pipe ⅜ In. Thick

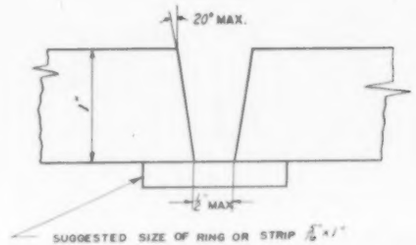


Fig. 23—Butt Joint for Operator Qualification, for Plate or Pipe 1 In. Thick

Fig. 20—Fillet-Weld-Soundness Test Specimen

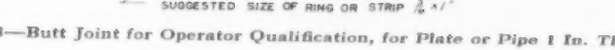


Fig. 23—Butt Joint for Operator Qualification, for Plate or Pipe 1 In. Thick

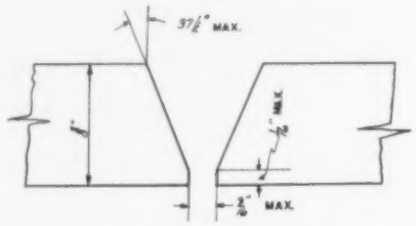


Fig. 24—Alternate Butt Joint for Operator Qualification, for Plate or Pipe ⅜ In. Thick (May Be Used for the Oxyacetylene Process Only)

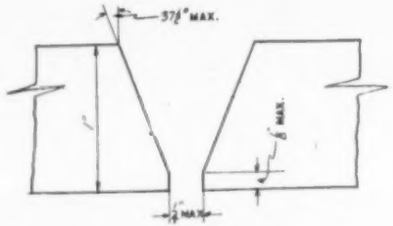


Fig. 25—Alternate Butt Joint for Operator Qualification, for Plate or Pipe 1 In. Thick (May Be Used for the Oxyacetylene Process Only)

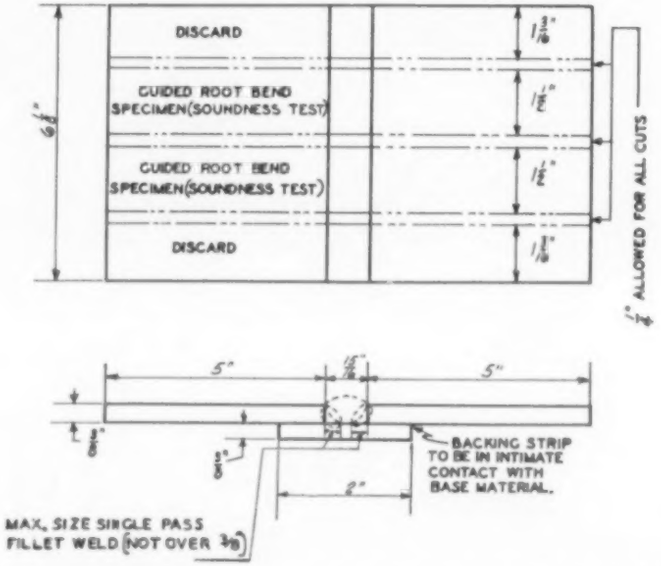
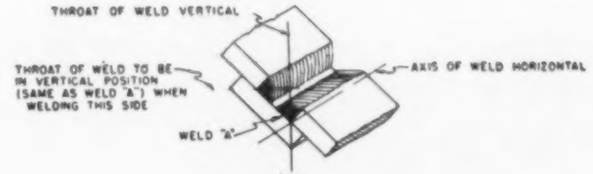
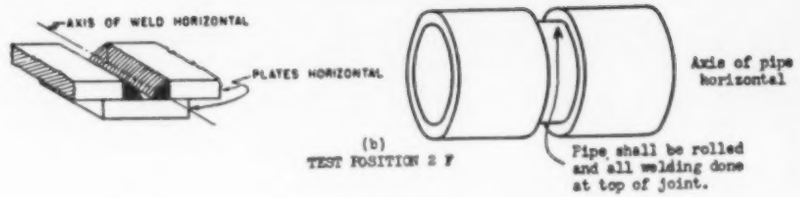


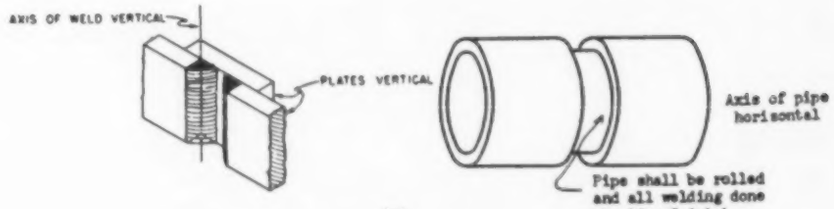
Fig. 26—Test Weld for Soundness Tests (for Operator Qualification Only)


THROAT OF WELD VERTICAL
THROAT OF WELD TO BE IN VERTICAL POSITION (SAME AS WELD 'A') WHEN WELDING THIS SIDE
AXIS OF WELD HORIZONTAL
WELD 'A'

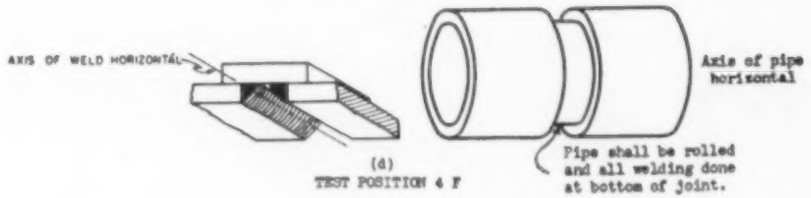
(a)
TEST POSITION 1 F


AXIS OF WELD HORIZONTAL
PLATES HORIZONTAL
Axis of pipe horizontal
Pipe shall be rolled and all welding done at top of joint.

(b)
TEST POSITION 2 F



(c)
TEST POSITION 3 F



(d)
TEST POSITION 4 F

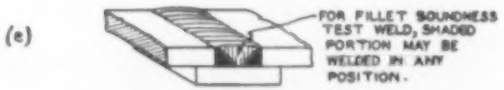


Fig. 27—Positions of Test Plates or Pipe for Fillet Welds (for Operator Qualification Only)

APPENDIX

RECOMMENDED FORMS OF PROCEDURE SPECIFICATIONS

I. Carbon Arc Welding Process:

PROCEDURE SPECIFICATION FOR CARBON ARC WELDING OF

(State Class of Object to be Welded)

Specification No.....

Date.....

Process: The welding shall be done by the Carbon Arc Process.

Base Metal: The base material shall conform to the Specifications for (insert here references to standard A. S. T. M. or other Code designations, or give the chemical analysis and physical properties).

Filler Metal: The filler metal shall conform to Classification Number —— of the American Welding Society's Specification for (insert here the title of the desired specification).

Position: The welding shall be done in the (give the position or positions in which the welding will be done. See Article 104.)

Preparation of Base Material: The edges or surfaces of the parts to be joined by welding shall be prepared by (state whether sheared, machined, ground, gas cut, etc.), as shown on the attached sketches and shall be cleaned of all oil or grease and excessive amounts of scale or rust, except that a thin coat of linseed oil, if present, need not be removed. (The sketches referred to should show the arrangement of parts to be welded with the spacing and details of the welding groove, if used. Such sketches should be comprehensive and cover the full range of material or base metal thicknesses to be welded.)

Size of Carbon or Graphite Electrodes: The range in size of carbon or graphite electrodes shall be as shown on the attached sketch. (The sketches referred to may be the same as mentioned under "Preparation of Base Material" or may be a separate set. They should show the range of electrode sizes for each thickness of material.)

Nature of Electric Current: The current used shall be (state whether direct or alternating and if alternating give the frequency). The base material shall be on the (state whether negative or positive) side of the line.

Method of Welding: The method of welding used shall be that known as (describe whether "backhand" or "forehand").

Current Characteristics: The approximate voltage and amperage during welding shall be as shown on the attached sketches. (The sketches referred to may be the same as those under "Preparation of Base Material" or under "Number of Layers and Passes of Welding.")

Size of Welding Rod: The size of rod used for the various base material thicknesses shall be as shown on the attached sketches. (The sketches referred to may be the same as mentioned under "Preparation of Base Material" or may be a separate set.)

Number of Layers and Passes of Welding: The number of layers and passes of welding used shall be as shown on the attached sketches. (The sketches referred to may be the same as mentioned under "Preparation of Base Material" or may be a separate set. They should show the range of thicknesses for which one, two or more layers are used.)

Cleaning: All slag or flux remaining on any bead of welding shall be removed before laying down the next successive bead.

Defects: Any cracks or blow-holes that appear on the surface of any bead of welding shall be removed by chipping, grinding or gas gouging before depositing the next successive bead of welding.

Peening: (If peening is to be used, it shall be incorporated as part of the Specifications, a description being given of the degree of peening to be done.)

Treatment of Under Side of Welding Groove: (The method of preparing the under or second side of a groove for welding on that side should be stated in this paragraph.)

Preheating: (This paragraph should describe any preheating that will be done.)

Heat Treatment: (This paragraph should describe any heat treatment or stress relieving that is given the welded parts before or after welding.)

Name of Manufacturer

II. Metal Arc Welding Process:

PROCEDURE SPECIFICATION FOR METAL ARC WELDING OF

(State Class of Object to be Welded)

Specification No.....

Date.....

Process: The welding shall be done by the Metal Arc Process.

Base Metal: The base material shall conform to the Specifications for (insert here references to standard A. S. T. M. or other Code designations, or give the chemical analysis and physical properties).

Filler Metal: The filler metal shall conform to Classification Number —— of the American Welding Society's Specification for (insert here the title of the desired specification).

Position: The welding shall be done in the (give the position or positions in which the welding will be done. See Article 104.)

Preparation of Base Material: The edges or surfaces of the parts to be joined by welding shall be prepared by (state whether sheared, machined, ground, gas cut, etc.), as shown on the attached sketches and shall be cleaned of all oil or grease and excessive amounts of scale or rust, except that a thin coat of linseed oil, if present, need not be removed. (The sketches referred to should show the arrangement of parts to be welded with the spacing and details of the welding groove, if used. Such sketches should be comprehensive and cover the full range of material or base metal thicknesses to be welded.)

Nature of Electric Current: The current used shall be (state whether direct or alternating and if alternating give the frequency). The base material shall be on the (state whether negative or positive) side of the line.

Welding Technique: The welding technique, electrode sizes, and mean voltages and currents for each electrode shall be substantially as shown on the attached sketches. (The sketches referred to may be the same as mentioned under "Preparation of Base Material" or may be separate sketches. They should show for the minimum thickness and for several intermediate thicknesses of base material, the welding technique to be used, whether weaving or beading, the number of layers or passes and diameter of electrode with the mean voltage and current for each layer or pass, and in the case of vertical welds, the progression of each pass, whether upward or downward.)

NOTE: Since, in the welding of many materials in the flat position and particularly for the ordinary mild steels, the proper welding "heat" can be readily determined by the appearance of the individual beads of welding, the use of a "Standard Appearance Weld" may be desirable for the flat position. Such a weld should be made in the maximum thickness that will be used in construction, except that the maximum thickness of the Standard Appearance Weld need not exceed $^3/_4$ in., and should show approximately 2 in. of the surface of each layer and a cross section through the weld at each layer, where such cross section is found necessary to produce a clearly understandable photograph. When a Standard Appearance Weld is used the following paragraph should be used in lieu of specifying current and voltage values.

Appearance of Welding Layers: The welding current and manner of depositing the weld metal shall be such that the layers of welding as deposited shall have the appearance shown on the photographs attached hereto. There shall be practically no undercutting on the side walls of the welding groove or the adjoining base material.

Cleaning: All slag or flux remaining on any bead of welding shall be removed before

Defects: Any cracks or blow-holes that appear on the surface of any layer of welding

(The method of preparing the under or second side of a groove for welding on that side should be stated in this paragraph.)

Preheating: (This paragraph should describe any preheating that will be done.)

Heat Treatment: (This paragraph should describe any heat treatment or stress relieving that is given the welded parts before or after welding.)

Name of Manufacturer

Cleaning: All slag or flux remaining on any bead of welding shall be removed before laying down the next successive bead.

Defects: Any cracks or blow-holes that appear on the surface of any bead of welding shall be removed by chipping, grinding or gas gouging before depositing the next successive bead of welding.

Peening: (If peening is to be used, it shall be incorporated as part of the Specifications, a description being given of the degree of peening to be done.)

Treatment of Under Side of Welding Groove: (The method of preparing the under or second side of a groove for welding on that side should be stated in this paragraph.)

Preheating: (This paragraph should describe any preheating that will be done.)

Heat Treatment: (This paragraph should describe any heat treatment or stress relieving that is given the welded parts before or after welding.)

Name of Manufacturer

III. Oxyacetylene Welding Process:

PROCEDURE SPECIFICATION FOR OXYACETYLENE WELDING OF

(State Class of Objects to be Welded)

Specification No.....

Date.....

Process: The welding shall be done by the Oxyacetylene Process

Base Metal: The base material shall conform to the Specifications for (insert here references to standard A. S. T. M. or other Code designations, or give the chemical analysis and physical properties).

Filler Metal: The filler metal shall conform to Classification Number —— of the American Welding Society's Specification for (insert here the title of the desired specification).

Position: The welding shall be done in the (give the position or positions in which the welding will be done. See Article 104.)

Preparation of Base Material: The edges or surfaces of the parts to be joined by welding shall be prepared by (state whether sheared, machined, ground, gas cut, etc.), as shown on the attached sketches and shall be cleaned of all oil or grease and excessive amounts of scale or rust, except that a thin coat of linseed oil, if present, need not be removed. (The sketches referred to should show the arrangement of parts to be welded with the spacing and details of the welding groove, if used. Such sketches should be comprehensive and cover the full range of material or base metal thicknesses to be welded.)

Size of Welding Tip: The range in size of welding tips used shall be as shown on the attached sketch. (The sketches referred to may be the same as mentioned under "Preparation of Base Material" or may be a separate set. They should show the range of tip sizes for each thickness of material.)

Nature of Flame: The flame used for welding shall be (state whether a neutral flame or one with slight excess of acetylene is to be used).

Method of Welding: The method of welding used shall be that known as (describe whether "backhand" or "forehand").

Size of Welding Rod: The size of rod used for the various base material thicknesses shall be as shown on the attached sketch. (The sketches referred to may be the same as mentioned under "Preparation of Base Material" or may be a separate set.)

Number of Layers of Welding: The number of layers of welding used shall be as shown on the attached sketches.(The sketches referred to may be the same as mentioned under "Preparation of Base Material" or may be a separate set. They should show the range of thicknesses for which one, two or more layers are used.)

Cleaning: All slag or flux remaining on any layer of welding shall be removed before laying down the next successive layer.

Defects: Any cracks or blow-holes that appear on the surface of any layer of welding shall be removed by chipping, grinding, or gas gouging before depositing the next successive bead of welding.

Peening: (If peening is to be used, it shall be incorporated as part of the Specifications, a description being given of the degree of peening to be done.)

Treatment of Under Side of Welding Groove: (The method of preparing the under or second side of a groove for welding on that side should be stated in this paragraph.)

Preheating: (This paragraph should describe any preheating that will be done.)

Heat Treatment: (This paragraph should describe any heat treatment or stress relieving that is given the welded parts before or after welding.)

Name of Manufacturer

PERSONNEL OF COMMITTEE ON STANDARD QUALIFICATION PROCEDURE

W. D. HALSEY, *Chairman*	The Hartford Steam Boiler Inspection & Insurance Co.
BUREAU OF SHIPS	Navy Department
P. R. CASSIDY	The Babcock & Wilcox Company
R. F. CAVANAGH	The Fidelity & Casualty Co. of New York
R. W. CLARK	General Electric Company
F. EDER	The R. W. Hunt Company
F. C. FANTZ	Midwest Piping & Supply Co.
H. O. HILL	Bethlehem Steel Company
C. W. OBERT, SR.	The Linde Air Products Company
J. F. RANDALL	Combustion Engineering Company
W. W. SCHMIDT	Rock Island Arsenal

PERSONNEL OF COMMITTEE ON GROUPING OF MATERIALS FOR PROCEDURE AND OPERATOR QUALIFICATION

C. H. JENNINGS, *Chairman*	Westinghouse Electric & Mfg. Company
L. C. BIBBER	Carnegie-Illinois Steel Corporation
A. G. BISSELL	Bureau of Ships, Navy Department
J. H. DEPPELER	Metal & Thermit Corporation
W. D. HALSEY	The Hartford Steam Boiler Inspection & Insurance Co.
N. L. MOCHEL	Westinghouse Electric & Mfg. Company
H. W. PIERCE	New York Shipbuilding Corp.
J. F. RANDALL	Combustion Engineering Company
CHARLES SCHENCK	Bethlehem Steel Company
W. G. THEISINGER	Lukens Steel Company

Practical Arc Welding of Tubular Structures*

By Francis H. Stevenson†

THERE has been considerable discussion about the use of arc welding in the aircraft industry. The last few years have seen quite an advancement in the use of this process in the fabrication of steel parts which are used in the airplane. Let us take, for instance, the motor mount, one of the most vital parts of an airplane, and follow its fabrication through the shop. Our first operation will be the welding of the legs; four separate jigs are required, one for each leg. These should be simple and easy to operate and the parts should be easily accessible for welding. The tubes are located by means of vee blocks and quick-acting clamps as shown in Fig. 1. Another feature of our jigs is the spring as shown in Fig. 2. This aids in the control of the expansion and contraction in the part. The tolerance given us on these parts is plus or minus $^1/_{32}$ inch, and as we have to take this into consideration, as well as the shrinkage caused from welding, our jigs are made $^1/_8$ inch longer than print dimension. Of this amount, $^1/_{16}$th inch is taken up in the first welding operation, leaving the balance to be taken care of in the final weld-operation. All the tubes used in the legs are nibbled to a template as shown in Fig. 3. In some cases, after nibbling, dressing up on the grinder is needed.

* Presented at the Western Metals Congress, AMERICAN WELDING SOCIETY, Biltmore Hotel, Los Angeles, Calif., May 19–22, 1941.

† Vega Airplane Company, Burbank, Calif.

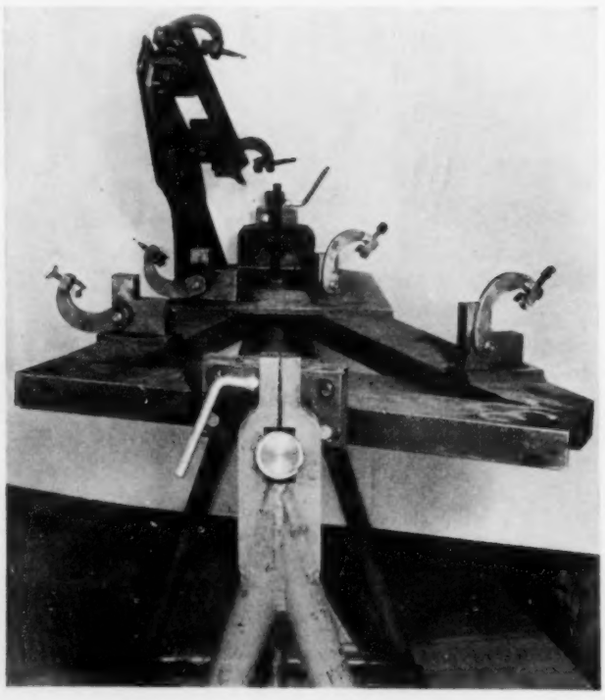


Fig. 1—Jig for Welding Motor Mounts

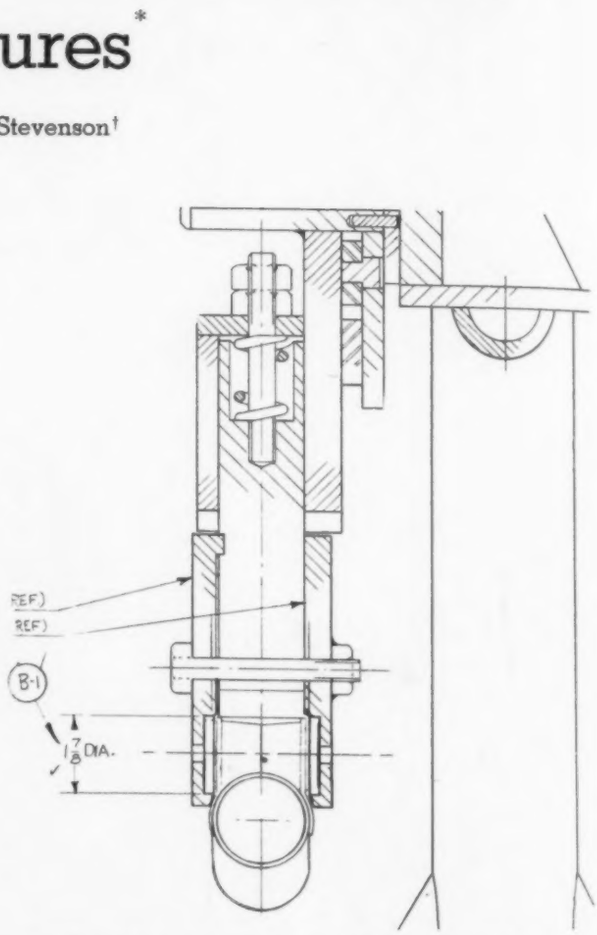


Fig. 2—Spring in Jigs Aids in Control of Expansion and Contraction

The slots necessary to take the web on the forging are cut on a high-speed cutting wheel. The bolt hole in the forging is not to print dimension and, in our case, is $^1/_8$ inch smaller; this allows for drilling and reaming on the finish operation. In some of the mounts a U plate and straps are used instead of a forging. However, the hole size should be smaller than the finish size called for on the print. This type of fitting is shown in Fig. 4. The tubes and forging are assembled on the jig, but before welding the fit must be O.K.'d by an inspector. Having received this O.K. you now proceed with the welding.

A very definite procedure must be followed. The first thing to do is to tack the tubes to the forging. This keeps the slots from spreading apart when welded. Preheating is next done, the temperature being 250 to 350° F. Start the weld on the center line of the tubing, at the hole ~~end of the~~ forging, and run the bead out to the edge of the web. This is done on both sides of the web. This procedure is shown in Fig. 5.

The machine setting used here is 20 volts across the arc and 100 to 115 amperes. A $^1/_8$-inch coated mild steel electrode is used. These parts are practically trouble-free as far as the welding is concerned. The

parts are next given a stress relief so they will set to the jig, the temperature being 500 to 600° F. They are allowed to cool in the jig, then taken out and put in bins to await the next operation. This same procedure is followed on the fabrication of all the legs.

Our next step is the welding of the ring forgings. These come to us in halves. The jig in this case is simple. It is two cups in line which hold each half of the forging in place and against each other so the welder can weld them together. This can either be made to turn by hand or by electric motor. No shrinkage is allowed on this jig. A $^3/_{32}$-inch rod is used with a machine setting of 20 volts across the arc and 75 amperes. There is never any trouble encountered in the welding of this fitting as far as cracks are concerned. However, care must be exercised to keep the halves in line so they will fit the ring. Neither a preheat nor a stress relief is used. Parts are taken out of the jig as fast as they are welded and put in the bins to await assembly to the ring.

The second operation to be considered will be the fabrication of the ring. Two jigs are required for this operation, one for welding the splice and one for welding

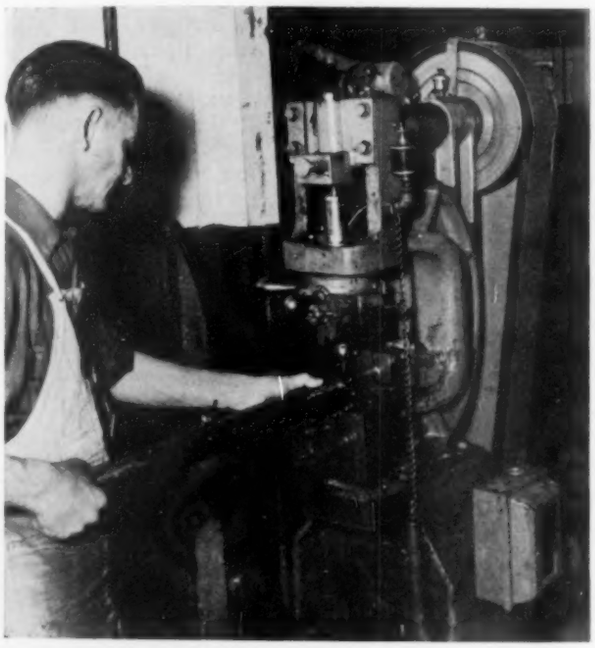


Fig. 3—Nibbling Tubes to a Template

the forgings to the ring. Figure 6 shows the splice jig and also our quick-acting clamps. Figure 7 shows the same jig with a ring tacked and ready for welding. The shrinkage allowance here is $^3/_{16}$ inch. The ring is rolled cold on the power rolls and after inspection we cut the splice, using a jig made like a carpenter's miter box, except that it is made from steel. Using this enables us to cut each splice the same. The ring is then put in the weld jig and the splice tacked. It is then O.K.'d by an inspector for welding. This is the only part of the mount that is welded by the oxyacetylene process. We do this because it is easier and the production time is about the same as the arc-welding process. However, if the quantity were sufficient, the operation could be accomplished by the use of a butt welder—in fact, some companies are now using this method.

The next step in this operation is the welding of the ring forgings to the ring. The jig used is shown on Fig. 8. It is mounted on a stand and can be revolved so that the welding operator can weld in the down hand

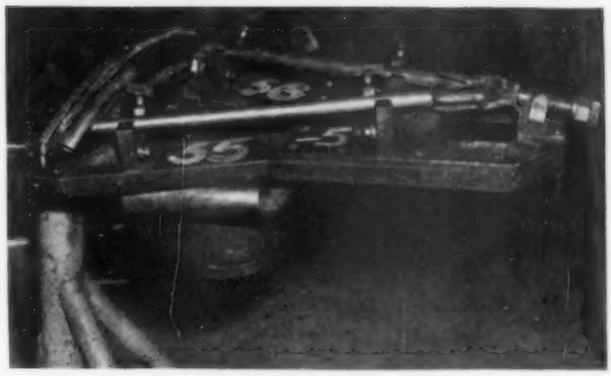


Fig. 4—Fitting Using a Plate and Straps

position most of the time. The shrinkage allowance is the same on this jig as on the previous one. About $^1/_8$ inch is taken up in the welding operation. Here we see the spring in use on the jig, a detail of which was shown in Fig. 2. The ring is held in the jig by three arms which can be tightened by a lever working on a cam. The forgings are held in cups. Rind and forgings are now assembled in the jig where they are O.K.'d by an inspector who, at the same time, passes on the welding of the splice. You are now ready to go ahead with the welding, the procedure being as follows:

A $^1/_8$ mild steel coated electrode is used with a machine setting of 20 volts across the arc and 120 amperes. We preheat this part, the temperature being 250 to 350° F. The welding procedure used is shown in Fig. 9. Starting with any one of the forgings, the inside is welded first, beginning from the center and going out to the edge. After both insides of the forging are welded go to the next forging which is as nearly opposite to the one just finished as possible, and repeat the procedure. This is done until all the forgings are welded on the inside. Now make the outside weld, completing each forging as you work along, going to the opposite one until the ring is complete. This is shown in Fig. 10. After all welding is finished, give the part a stress relief, the temperature being 500 to 600° F. Leave the part in the jig to cool, then take it out and put it in the bin to await

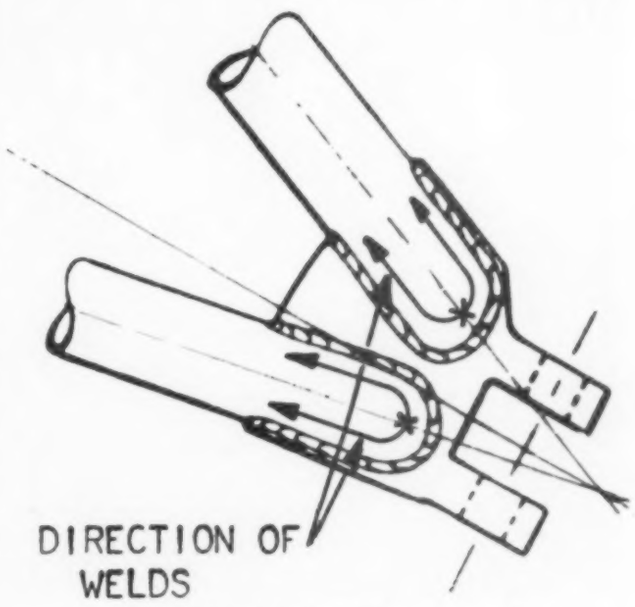


Fig. 5—Procedure for Welding Fitting in Fig. 4

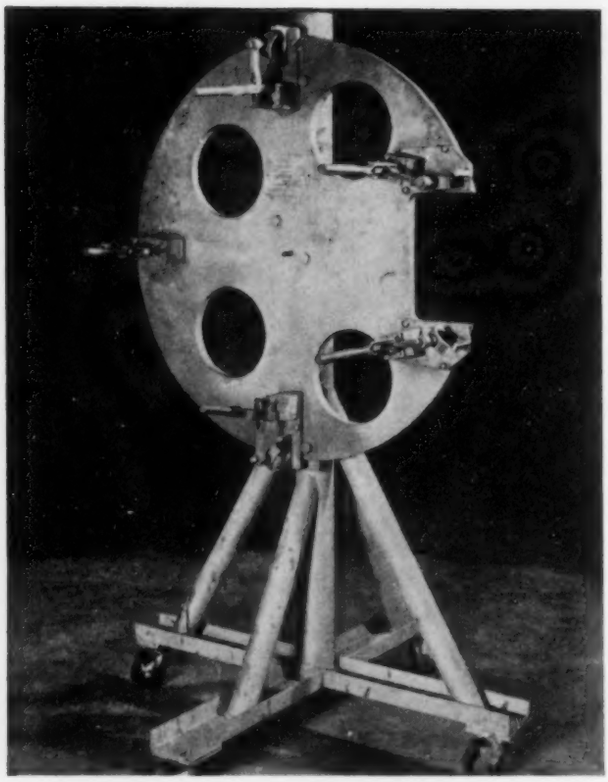


Fig. 6—Splice Jig for Welding Rings

the final welding. This part is almost trouble-free. However, occasionally a crack will develop. These are mainly caused from incorrect welding procedure.

Our next operation to be considered is the welding of the ring to the legs in the main assembly jig. This jig is shown in Fig. 11. The jig itself is mounted on a bearing and counterbalanced which allows it to be turned easily. This enables the welder to weld in the down hand position most of the time. The face of the jig where the ring is mounted is the same as the ring jig except for the shrinkage allowance which in this case is $^1/_{16}$ inch on the diameter and the lever is also eliminated. The legs are located in the angles and held there with clamps. The feet are located by fittings on the back plate. These fittings also have a spring tension on them. The shrinkage allowed is $^1/_{16}$ inch in the length. The ring and the legs which have already been welded are now assembled in this jig. The fit-up is now passed upon by an inspector and we are ready for the welding operation. This is shown in Fig. 12.

As in previous operations, preheat is used, this being 250 to 350° F. These welds are split and when one tube is finished the one opposite is then welded. After all welding is done that is possible in the jig, the mount is then taken out and the welding finished. Some trouble might occur at this stage in the nature of cracks. However, most of that can be eliminated by correct fit-up. Our next step is to tack in the gussets; this is done off the jig by using gas welding. We use this method because we are able to make small, neat tacks which are easily absorbed by the arc. The shrinkage or warpage during this operation is negligible. After all the gussets are tacked into place, they are inspected and O.K.'d ready for welding. A frame is then bolted on the feet. This is done to keep the legs in place while gussets are being welded. This could be mounted on a stand and used instead of putting it on the bench. The electrode used is mild steel coated and is $^3/_{32}$ inch in diameter. The current used will be 20 to 25 volts across the arc and 100 to 120 amperes. Here, as in the previous operations, a preheat is used, the temperature being the same as heretofore mentioned. Your welding procedure must be watched very carefully, with the outside of the gussets being welded first. This is shown in Fig. 13. After one group of gussets is welded completely on the outside, then the next group, which is directly opposite, is welded and this procedure is followed until all outside welding is finished.

Our next step is to weld the inside of the gussets. The

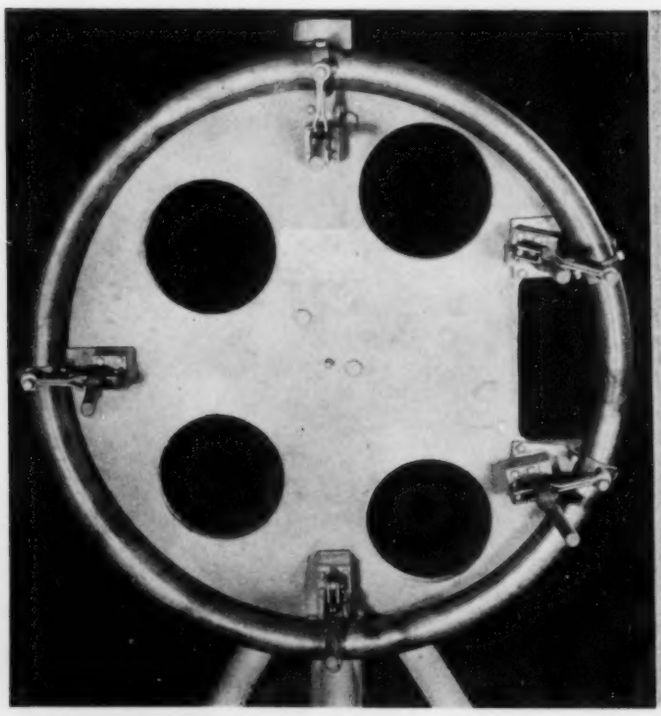


Fig. 7—Ring Tacked and Ready for Welding

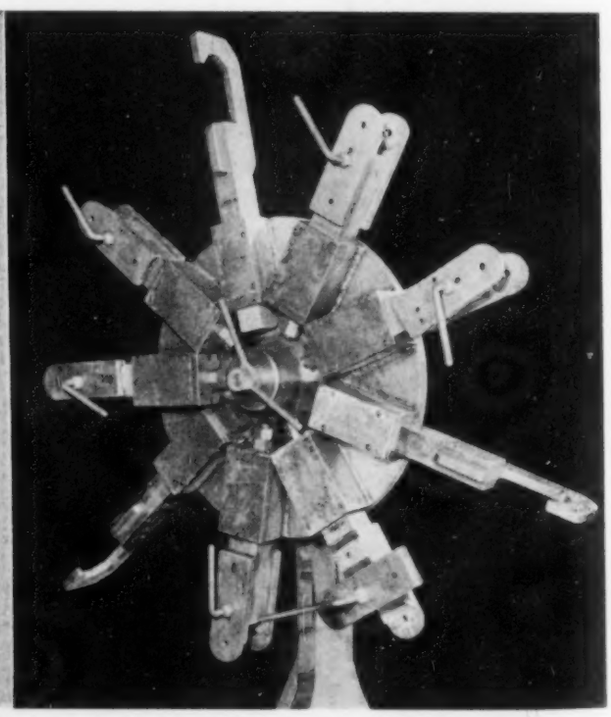
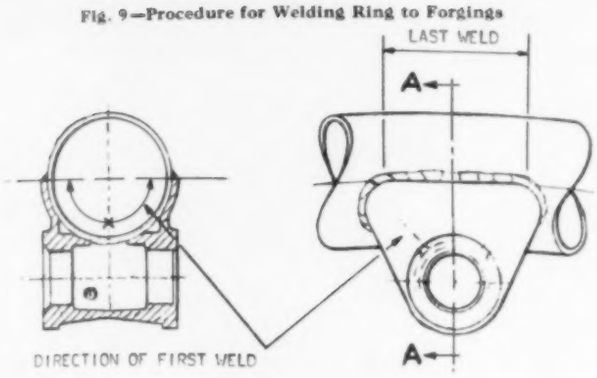


Fig. 8—Jig for Welding Ring Forgings to Ring

Fig. 9—Procedure for Welding Ring to Forgings



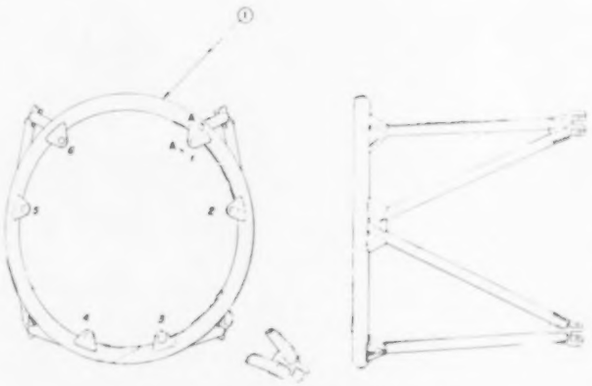


Fig. 10—Procedure for Welding Forgings to Rings

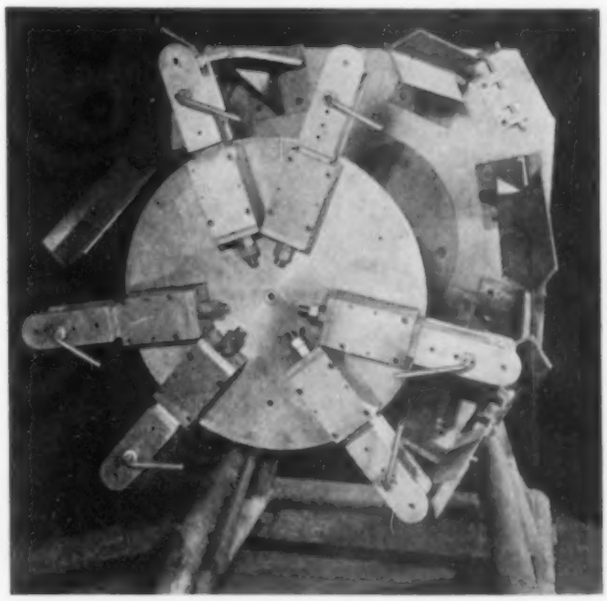
same procedure is used as mentioned for the outside, with the addition of the last weld in each group of gussets being made on the back as shown in Fig. 13. The mount is then put back in the main assembly jig for cowling clips to be welded on, if used, and a stress relief given. This is done to set the mount to the jig so that it will be as nearly perfect as possible for the following machine operation. The temperature used for the relief operation is usually 500 to 600° F. The amount is left in the jig to cool, then taken out and checked for trueness and put in a drill jig where the holes in the feet are drilled and reamed. It is then sent to the machine shop where the engine mount forgings are drilled, reamed and spotfaced. The mount is now ready for the final inspection.

In the forepart of this paper the writer has endeavored to take the mount through each step necessary to its fabrication in the shop. The latter part of the paper will be a summary of the points mentioned previously. The number of jigs necessary to build this mount is only seven for the welding. This is done because it has been our experience that, by breaking the assembly down into as many subunits as is practical, we are able to make a better product and also keep our production time down. One of the main points of our jigs is the spring shown in Fig. 2. This helps considerably in the control and expansion of the parts. As our tolerance is plus or minus $^1/_{32}$ inch, it is an easy matter to adjust the spring to take care of any discrepancy that might occur from time to time. One thing that makes for better welding jigs that the shop man can use, is the fact that the tool designer and the foreman get together and exchange ideas on the jigs and the number to be used on a certain job. When the tool designer has completed the drawing on a particular jig it is submitted, for his O.K., to the foreman of the department in which it is to be used. In our company this has eliminated a considerable amount of jig trouble.

The shrinkage allowances that are given must be taken only as approximate. However, for the first mount used, they will be quite satisfactory. In most cases very little adjustment will be necessary on the jigs. We do not have any rules regarding figuring the amount of shrinkage in a part, since that depends entirely on the size and shape of the part, or how many subunits into which it will be broken down, and the welding process to be used. We arrive at the figures used from past experiences in the building of other parts of this nature.

From the foregoing it should not be concluded that all is clear sailing in the fabrication of this part. We in the shop encounter quite a number of troubles—one of the main ones being cracks. These may be caused from a number of reasons, bad fit-up, jig too tight, too rapid cooling immediately after welding, wrong direction in welding, and poor operators. Let us take each point separately and see what can be done to cure them. Bad

Fig. 11—Jig for Welding Ring to Legs



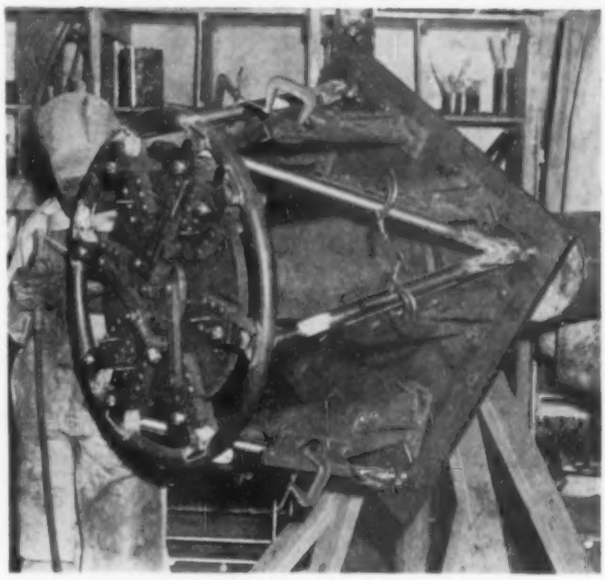


Fig. 12—Ready to Weld Ring to Legs

fit-up can be eliminated by giving proper instruction to the metal fitter doing the fit-up work. If the jig is too tight, i.e., parts clamped in the jig so they are unable to move, leave them loose enough so they can expand and contract. Jig made without allowing for expansion or contraction—this should be taken care of when the jig is designed. Cooling too rapidly can be eliminated by establishing a procedure and sticking to it. Poor operators—always put a competent operator on a job of this nature. We might sum all this up and say the way to overcome most of the welding trouble is to establish a correct welding procedure and stay with it, this, of course, only applying if jigging is correct and you have highly skilled operators. As you build more of these parts you will find that there are going to be some minor changes in the welding procedure which will speed up the production and also increase the quality of the part. All welding procedure should, as a general rule, be worked out on the first ten units produced. This, however, does not mean that you should stop looking for ways and means to better the procedure.

There is another source of trouble and that is in the steel and the forming of the parts such as the gussets. Be sure your steel is kept on the low side of the carbon range, because we have found, particularly in X4130, that when it is on the high side cracks are found when everything else is O.K. When the parts are formed, be sure that it is done so that you do not weld parallel to the grain of the metal but rather across it. Most of your troubles are encountered in the first few units you build; however, a constant watch is needed on every phase of the work to be sure your troubles are kept down to an absolute minimum.

A few words in regard to the inspection of this particular part. We have what is known as line inspection; as was mentioned previously each subunit is O.K'd by an inspector. X-ray and magnaflux inspection is also used. It is our practice to have one part in every ten X-rayed; this procedure is of great benefit to the welder and the foreman as it enables the foreman to show the welder where he is weak and the fault is corrected. It also keeps the quality of the work at a very high level.

There has been considerable discussion on the types of electrodes used in the welding of X4130 steel of which our steel parts are fabricated. It has been the experience in our welding shop that a good, mild steel rod is satisfactory. The coating must be uniform and not too heavy. It is on the unevenness of the coating where the welding operator has most of his trouble with a rod. Our reason for using a rod of this type is because parts are designed with the use of this type of rod in mind, also it is easy for the average operator to use and be able to make a satisfactory weld. There are, however, certain parts on which, due to subsequent heat treating, we use an alloy rod. The rod sizes most commonly used are $^5/_{64}$, $^3/_{32}$ and $^1/_8$ inch and not to exceed 12 inches in length. Any longer rod in the smaller sizes has a tendency to weave around and is much harder to control.

There are two different schools of thought on the setting of the welding machine—one that the setting should be stated on the print and the operator use that setting, the other that the man who is operating the welding machine do the setting. It has been the shop practice of our company to let the man set his machine. We have found by checking with at least ten different men that, at the most, there is only ten amperes' difference in the settings. As a general rule, for most of the welding on the motor mount, the setting will be between 20 to 25 volts across the arc and 80 to 120 amperes.

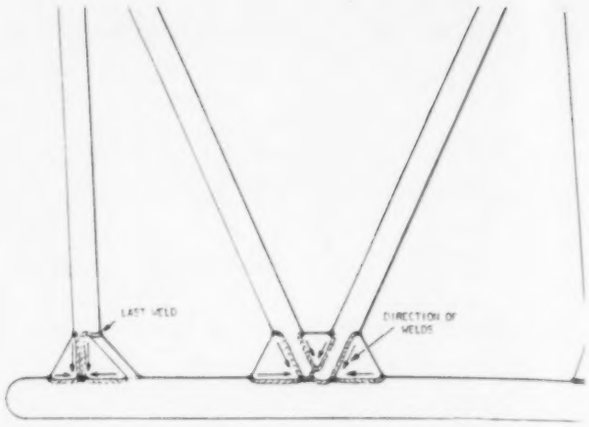


Fig. 13—Procedure for Welding in Gussets

It is interesting to note what savings can be accomplished by the use of the arc-welding process on tubular structures in the aircraft industry. For example, let us take a landing gear fulcrum. By the oxyacetylene process, it took a welder nine hours to build one complete. By using the arc welding we are able to weld two and one-half parts in eight hours. The same can be said of a number of other parts. However, in many cases rejigging is necessary but even with that cost added there is still sufficient saving to warrant changing to the arc-welding process. In our company, we seldom weld any parts by the arc which have a wall thickness less than 0.058 in. However, all our heavy parts are arc welded. This includes motor mounts, support bays and a number of different kinds of struts. We are now doing considerable arc welding on our stainless steel exhaust collector rings. To make the arc-welding job a success, the part should be designed for it from the start as well as the jigs because it is sometimes difficult to change from oxyacetylene to arc when the part was originally designed for oxyacetylene. In our company we try to use the process which is the most practical both from the standpoint of the ease with which it can be fabricated in the shop and the cost of the finished part.

In conclusion it should be stressed that consistently good results from a welding department are assured when management (1) designs for arc welding, (2) establishes a procedure which will give the results expected, and (3) qualifies the welding operators to follow that procedure.

(*Continued from page 428*)

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Welding Society

ACTIVITIES — Related Events

THE PRESIDENT'S MESSAGE

The Western Metals Congress was a distinct success.

The WELDING SOCIETY program was well organized. Its technical sessions featured primarily aircraft problems and covered interesting developments of the Pacific Coast airplane companies which have been prominent in welding developments.

The Metals Congress sessions offered the SOCIETY the opportunity of contacting the airplane industry in respect to welding standardization and research activities. The problems of the aircraft industry were discussed in detail and a constructive program of work outlined and tentatively approved.

The programs involve the organization of a new Aircraft Welding Standards Committee to function in cooperation with the National Aircraft Standards Committee. The SOCIETY has the offer of technical assistance to be made available to the aircraft industry which will be of great assistance in accelerating the standardization program. It is hoped that the work will be organized before this message is printed. The program has the approval of the Board of Directors.

The conferences held were of great value in increasing the usefulness of the Welding Research Committee. An Aircraft Welding Research Committee will be organized for cooperative research activities. The Committee is assured of both technical and financial aid.

The Metals Congress contacts have emphasized the needs of expanding the educational program. One of the problems today is the training of welding operators in various school systems. The SOCIETY'S current work in standardizing this training is badly needed and it is hoped that it will be available in the near future.

In these times of expanding National Defense production, the technical society is of the greatest value for the dissemination of technical knowledge. Some aircraft plants have made marked progress in the application of some welding processes; others have developed other processes and some have retained less developed methods. In times of forced expansion such as the present, it is a general policy to make technical information available for the good of the industry. There is consequently a rare opportunity for a technical society to be of service as a medium of dissemination of technical developments, both in standardization activities and in educational programs.

The Pacific Coast District, under District Vice-President L. W. Delhi, has been far-sighted in planning these activities of the Western Metals Congress. The SOCIETY owes a debt of gratitude to him and to the Los Angeles Section under the chairmanship of Mr. C. W. Roberts.

RULES FOR FIELD WELDING OF STEEL STORAGE TANKS

Following the SOCIETY'S regular procedure, the Committee on Rules for Field Welding of Storage Tanks has prepared a revision of its original report, which has been approved by the Executive Committee and published under the title, "Rules for Field Welding of Steel Storage Tanks." The original Rules, which were published as tentative approximately a year ago, appeared in the August 1940 issue of THE WELDING JOURNAL. The present report contains a number of changes from the original, most of which, however, were designed simply to improve and clarify the wording and not to change the intent of the requirements. An Appendix has been added giving reference to a number of storage tank specifications that cover design, unit stresses and other applicable data.

The new Rules for Field Welding of Steel Storage Tanks may be obtained from the AMERICAN WELDING SOCIETY, 33 West 39th Street, New York, N. Y., for 25¢ per copy.

ADDRESS BEFORE NATIONAL BOARD OF BOILER AND PRESSURE VESSEL INSPECTORS

In the absence of Colonel Jenks, President of the Society, Mr. J. J. Crowe, Past President of the Society, gave the following address:

"I know that Colonel Jenks, the President, would like to have been here this morning and tell you gentlemen about some of the things that the AMERICAN WELDING SOCIETY is doing in the interests of welding and the preparation of codes applicable to welding and, more particularly, in the interest of welding as applied to pressure vessels, and of the efforts that are being made to obtain the adoption of a minimum number of uniform codes.

"Right now a committee of the AMERICAN WELDING SOCIETY is working on a plan of reorganization of the Technical Activities which has as its object to obtain a closer and better cooperation between our Society, the AMERICAN WELDING SOCIETY and other societies and the various commercial, technical and scientific interests.

"While most of our contacts with the National Board have been indirect, that is, through the A. S. M. E., Mr. Obert, our representative, has always reported that the most cordial relations existed and we hope that these relations that have been established will continue.

"Working with the A. S. M. E. we have developed a code for welding that is apparently satisfactory and one that is generally adopted, but conditions are changing so fast, new steels are being developed, new welding processes are coming into use and it is more important than ever that we stay with the problem and all work together for the best and one uniform code that will permit a pressure vessel manufactured anywhere to be used anywhere.

"In closing I should like to repeat that the cooperation received from the National Board is deeply appreciated by the AMERICAN WELDING SOCIETY.

WESTERN METALS CONGRESS

Countless new developments in alloys, fabrication and application of metals were discussed May 19th to 23rd, when the Fourth Western Metal Congress was held in Los Angeles.

Technical sessions of the Congress and displays in the Western Metal Exposition resulted in an interchange of scientific knowledge between East and West, which will advance national defense, aviation, oil, chemical, general manufacturing and mining industries.

Sessions were held by the American Society for Metals, AMERICAN WELDING SOCIETY and American Foundrymen's Association. Nearly 50 lectures were delivered by distinguished metallurgical scientists. Many speakers gave two, three or four lectures on the same topic to cover all details completely.

Attendance at the Exposition totaled 39,212, while approximately 5000 were seated at the technical sessions, according to W. H. Eisenman, secretary of the American Society for Metals.

Demand for metallurgical equipment in the West is at such a peak that virtually every mechanism exhibited in the Exposition was sold from the floor, and thousands of dollars worth of additional orders were written.

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Snapped at the Western Metals Congress Dinner

Attendance came mainly from the nine western states, but nearly 400 technical engineers and research physicists from the East were present to demonstrate developments in metal science.

The Board of Trustees, American Society for Metals, said San Francisco is being considered as the next Western Metal Congress city. The time probably will be the third week in April 1943. The National Metal Congress will be held in Philadelphia October 20–24, 1941.

The AMERICAN WELDING SOCIETY sessions were exceedingly well attended. A program of the technical papers presented follows:

Monday, May 19th

"Manual and Machine Plane Grooving" by E. V. David, Air Reduction Sales Co., New York, N. Y.

"All Welded Ship Construction," by L. W. Delhi, Western Pipe & Steel Co., Regional Vice-Pres., A. W. S., San Francisco, Calif.

Tuesday, May 20th

"Resistance Welding in Aircraft," by J. H. Cooper, Taylor-Winfield Corp., Warren, Ohio.

"Spot Weldability of Aluminum Alloys," by C. L. Hibert, Consolidated Aircraft Corp., San Diego, Calif.

"Welding of Stainless Steels," by Dr. V. N. Krivobok, Lockheed Aircraft Corp., Burbank, Calif.

Wednesday, May 21st

"The Training of Welding Operators," by T. B. Jefferson, *The Welding Engineer*, Chicago, Ill.

"High Pressure, High Temperature Piping," by F. C. Fantz, Midwest Piping & Supply Co., St. Louis, Mo.

"Codes," by Russell Love, Southwest Welding & Mfg. Co., Alhambra, Calif.

Thursday, May 22nd

"Some Experiences in Welding Heavy Gauge Chrome-Molybdenum Steel for Impact Applications," by Prof. N. F. Ward, University of California, Berkeley.

"Arc Welding of Chrome-Molybdenum Tubing and Plates in the Aircraft Industry," by F. R. Kostoch, North American Aviation, Inc., Inglewood, Calif.

"Practical Arc Welding Applications on Tubular Structures in Aircraft," by F. H. Stevenson, Vega Airplane Co., Burbank, Calif.

It is planned to publish most of these papers in THE WELDING JOURNAL as they become available. Two of them were published in the June issue, others are published in the current issue.

Special credit is due Mr. L. W. Delhi, General Chairman of the Congress and Regional Vice-President of the A. W. S., San Francisco District, and to Mr. J. C. Gowing, Chairman of the Program Committee and Chairman Elect of the Section; also to Mr. C. W. Roberts, Chairman of the Los Angeles Section, Mr. J. C. Blake, Entertainment Committee Chairman, Mr. M. H. Turner, Registration Chairman, Mr. P. D. McElfish, Coordinating Chairman, and Mr. E. O. Williams, Publicity Chairman.

An Honorary Luncheon was given by the Section to the National Officers, which was attended by approximately one hundred industrial leaders in Los Angeles. Mr. C. W. Roberts, Chairman of the Los Angeles Section, briefly described the objectives of the Congress and introduced many of the celebrities present from the Los Angeles and other Sections of the Society. He welcomed all those present to participate in the Congress and called upon the National President, Colonel G. F. Jenks, to briefly say a few words about the activities of the Society. Other addresses were given by Mr. L. W. Delhi, Regional Vice-President of the A. W. S., Mr. E. V. David, Chairman, Convention Committee, and W. Spraragen, Technical Secretary and Editor.

One of the principal purposes of the visit of the President and the Technical Secretary to the Coast was the organization of an Aircraft Welding Standards Committee and an Aircraft Welding Research Committee. Considerable progress was made in this direction as a result of this visit.

On Thursday members of the A. W. S. and other participating societies joined with the A. S. M. in a dinner dance and participated in the general entertainment.

The territory covered by the Los Angeles Section of the AMERICAN WELDING SOCIETY is now emerging as the largest concentrated shipbuilding center in the West. The total backlog as of the end of

SAVE MONEY . . . BY WELDING

Jaw Plates, Gyratory and Roll Crushers, Shovel Teeth, Hammers, Tractor Tread Grousers

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MANGANAL

Reg. U. S. Pat. Office. U. S. Patents 1,876,738—1,947,167—2,021,945

11 to 13% Manganese Nickel Steel

WELDING ELECTRODES, WEDGE and APPLICATOR BARS, HOT ROLLED PLATES

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Buy "Proven Fluxes" with Years of Guaranteed Satisfaction behind them

The Trade-Name is "ANTI-BORAX"

Ask for Them *Unequalled for Quality*

A Flux for every metal: Cast Iron Welding Flux No. 1; Brazing Flux No. 2; Braz-Cast Flux No. 4, for bronze-welding cast iron; "ABC" Aluminum Flux No. 8 for sheet Aluminum and all alloys of Aluminum; Stainless Steel Flux No. 9; Silver Solder Brazing Flux No. 10; "Anti-Borax" Tinning Compound No. 11.

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ANTI-BORAX COMPOUND COMPANY
Fort Wayne, Indiana

We can help you do a better welding job!

ROLLED steel construction, like many other production practices, has been subjected to intense study. And, as in other producing methods, there have been vast and important improvements. All along the American industrial front, many practices and methods which served in ordinary times are being shelved for newer and better ways.

If you have a problem—if you need help in anything embracing welding construction, we are equipped to help you. It's been the job of our experienced welding engineers to determine just where and how rolled steels will best serve in all types of welding construction. Our specialized knowledge equips us to offer a service to the welding industry which we believe is as important as the wide selection of U·S·S Rolled Steels we make.

Write today for more complete information and technical data — tell us your problem, or ask one of our experts to call. These men will gladly work with you—no obligation.

U·S·S ROLLED STEELS *for* WELDING

CARNEGIE-ILLINOIS STEEL CORPORATION, *Pittsburgh and Chicago*
COLUMBIA STEEL COMPANY, *San Francisco*
TENNESSEE COAL, IRON & RAILROAD COMPANY, *Birmingham*
United States Steel Export Company, New York

UNITED STATES STEEL

April is $284,902,098 which is 1/5 of the total Pacific Coast backlog of $1,500,000,000. There has been a tendency lately to transfer several large contracts for east coast yards to California because of increased facilities in Los Angeles Harbor due to erection of new ways and formation of new shipbuilding companies.

Three seaplane tenders were transferred to the L. A. Shipbuilding & Drydock Company for a total cost of $37,500,000.

California Shipbuilding Company has an additional contract for twenty-four more cargo ships costing $39,600,000.

South Coast Boat Company at Newport, California, formerly one of the largest exclusive yacht builders, has been awarded six mine sweepers, which involves $2,016,000. It looks like the yachting fraternity will have to have priority numbers in order to have their boats repaired.

Other relatively small contracts were awarded in April to the various yards, totaling $2,120,000.

BOARD OF DIRECTORS MEETING

The Board of Directors of the AMERICAN WELDING SOCIETY held a meeting in the Engineering Societies Building, New York, on June 3, 1941. President Jenks presided. The following were present: C. A. Adams, D. Arnott, H. C. Boardman, D. H. Corey, J. H. Deppeler, J. D. Gordon, H. O. Hill, L. S. Moisseiff, H. M. Priest, H. S. Smith; By invitation: R. W. Clark, D. S. Jacobus, J. F. Lincoln (members of Executive Committee): W. Spraragen, Technical Secretary, and M. M. Kelly, Secretary.

Finances

The finances of the SOCIETY are in a healthy state as indicated in a report submitted by Treasurer Moisseiff. It was voted that recommendation of Finance Committee in regard to placing 1% of the SOCIETY'S gross income for the fiscal year commencing October 1, 1940, in the Permanent Reserve Fund, be approved.

The Treasurer further reported that his Committee has been making a study of the advisability of establishing a retirement plan for SOCIETY employees. Figures and information have to date been secured from one insurance company and from a technical society.

The Finance Committee was requested to make a careful study of the numerous types of retirement plans used by other institutions, with probable costs and advantages of such plans, and in its study to confer with other technical societies and leading insurance companies, with a view of submitting report to the Board of Directors at its next meeting. Suggestion was made that consideration be given an independent retirement system.

McCune Memorial

It was reported that the Executive Committee by letter ballot had approved of the establishment of a Memorial in the form of a bronze plaque and that the cost of such plaque would be in the neighborhood of $125. Sketch of plaque and inscription to appear thereon were submitted for review. Arrangements are being made to unveil the plaque at the annual meeting of the Society in Philadelphia.

By-Law Amendments

A number of suggested changes in the By-Laws were reviewed and approved. These relate to the district meetings, meetings and notices, exhibitions and refunds to Sections. Inasmuch as these changes in By-Laws will be submitted to the membership for vote, detailed review is not given in this JOURNAL.

Automotive and Aircraft Welding Committee

Consideration was given to the petition of the Automotive Welding Council that that body be appointed a standing committee of the AMERICAN WELDING SOCIETY to be known as the Automotive and Aircraft Welding Committee. It was voted that the president be authorized to appoint an Automotive Welding Advisory Committee for the purpose of making recommendation to the Board of Directors of the SOCIETY with respect to the needs of the automotive industry in respect to welding. The President stated it is his intention to consult with the Detroit Section officers and members of the Automotive Welding Council before making this appointment.

Welding Handbook

Progress report was submitted by the Chairman of the Welding Handbook Committee, Dr. D. S. Jacobus. It is hoped that the second edition of the Handbook will be available during the latter part of 1941. Prices for the Handbook, including a prepublication offer, were approved as follows:

Prepublication offer: If ordered before August 31, 1941. Price to members and non-members in U. S. and possessions, $4.00; in foreign countries, $4.50. Inasmuch as the purpose of this prepublication offer is to provide the SOCIETY with funds for publishing the book, all orders must be accompanied by check. No discount will be allowed to booksellers from the above prices. Important Notice! Regular price to non-members after August 31, 1941—$6.00. The price of the first copy of the book to members when issued will be: $4.00 to members in the Associate, Operating and Student grades; free to members in the Sustaining and Member grades; additional copies to all members, $5.00.

Committee Appointments

The following committee appointments were made upon recommendation of the Committee on Outline of Work.

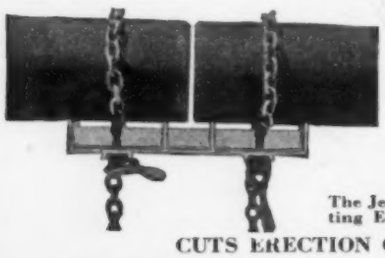
Resistance Welding Standards Committee: E. O'Hara, The Cincinnati Gas & Electric Co., Cincinnati, Ohio; T. J. Brosnan, Buffalo Niagara Electric Corp., Buffalo, New York.

Committee on Rules for Field Welding of Storage Tanks: F. L. Plummer, Hammond Iron Works, Warren, Penna.

Committees to Prepare Standards for Aircraft Industry: On the recommendation of Colonel Jenks it was voted to authorize the appointment of a committee on Aircraft Welding Standards in place of the Committee on Standards for the Aircraft Industry proposed by the Outline of Work Committee, and to request the Outline of Work Committee to submit for approval at a later meeting exact scope and personnel for the proposed Aircraft Welding Standards Committee.

The Society had received offers from the Taylor-Winfield Co. to make available the services of its expert, Mr. George Mikhalapov. Mr. J. F. Lincoln of The Lincoln Electric Company offered to provide the services of an expert to assist in the standardization and educational program in the aircraft field in so far as fusion welding is concerned.

PIPE WELDING TOOLS THAT MAKE WELDING PAY



Pipe Clamps
Flange Clamps
Elbow Clamps
Angle Clamps
Pipe Markers

TWO SIZES
½ to 8 in. 8 to 16 in.
Light—Adjustable—Fast

The Jewel System of Pipe and Fitting Erection Ready for the Weld

CUTS ERECTION COSTS

Keeps the Welder Welding Instead of Waiting

JEWEL MANUFACTURING COMPANY

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★ Welding and welders have come into their own. And the search for electrodes that help men get better welds, and more uniform welds, in the shortest possible time, has led straight to PAGE. . . . You will find it very much worthwhile to call in your local Distributor of PAGE ELECTRODES, ask for his recommendations to fit your work and get from him a well-illustrated booklet on each of the PAGE ELECTRODES.

PAGE HI-TENSILE "F"—High speed welding, a shield-arc type electrode for vertical, horizontal or overhead.

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PAGE-ALLEGHENY STAINLESS—Shield-arc type electrodes from which you can select one that will give you weld metal in welds that equals the stainless you weld.

PAGE ELECTRODES

PAGE STEEL AND WIRE DIVISION • MONESSEN • PENNSYLVANIA

In Business for Your Safety

AMERICAN CHAIN & CABLE COMPANY, Inc.

President Jenks stressed the needs of the aircraft industry for welding standards.

The situation, the President stated, offers the SOCIETY a splendid opportunity to indicate its desire to assist in the National Defense Program. An advance of the order of $1000 or $2000, it is believed, would get the Resistance Welding Standardization Program started and at the same time would serve to convince the aircraft industry and governmental agencies of the SOCIETY's sincerity in desiring to sponsor the aircraft project.

It was voted that an appropriation not to exceed $2000 be advanced toward the aircraft welding standardization program.

Honorary Director

The Chairman of the 1941 Nominating Committee reported that it is the recommendation of that Committee that Dr. Comfort A. Adams be made an Honorary Director of the Society. Upon motion, duly seconded, it was unanimously voted that Dr. Adams be made an Honorary Director of the SOCIETY, and that the By-Laws Committee be requested to make suitable provision for this office in the SOCIETY By-Laws.

UNITED STATES CIVIL SERVICE COMMISSION WASHINGTON, D. C.

The U. S. Civil Service Commission wishes to call your special attention to the Engineer examination announced April 7, 1941. The new Engineer examination includes all branches of engineering except chemical, metallurgical, marine and naval architecture. It also includes all grades except the Junior grade (positions requiring no experience at $2000 a year). Junior Engineer examinations are open under Annct. Nos. 51 and 53 in various fields of engineering.

Engineers qualified in the following specialized fields are particularly needed for the National Defense program: Aeronautical, Agricultural (Farm Machinery), Construction (Airports and Buildings), Heating and Ventilating, Mechanical (Industrial Production, Diesel Design), Ordnance, Radio, Safety, Sanitary Structural (Building Design) and Welding.

The Engineer announcement gives further details concerning the examination and instructions for obtaining and filing applications. Applications will be rated as they are received at the Commission's Washington Office until June 30, 1942; however, qualified persons are urged to file their applications at once.

ABBREVIATIONS AND TERMS

The American Standards Association reports completion of the revision of American Standard Abbreviations for Scientific and Engineering Terms. This standard, providing as it does the shorthand of engineering and scientific language, has a very wide application. It includes such common terms as pounds per square in (psi), dollar ($) and dozen (doz), as well as kilograms per second (kgps), reactive volt-ampere (var) and British thermal unit (Btu).

The standard has been developed by a group of engineers, editors and scientists representing many national organizations. Leadership for the work has been taken by the American Association for the Advancement of Science, the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Society of Mechanical Engineers and the Society for the Promotion of Engineering Education.

OUTPUT OF WELDING WIRE AT NEW PEAK

Production of steel welding wire rose to 238,795,000 pounds in 1940, a new high record, according to information received by the American Iron and Steel Institute.

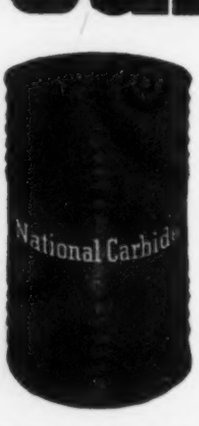
The increase reflected wider use of welding processes than ever before in shipbuilding, construction work, the manufacture of home equipment and numerous other fields.

Last year's output of welding wire represented an increase of 30 per cent over the 1939 production of 183,436,000 pounds the highest total previously recorded.

Between 1932 and 1940 the production of steel welding wire rose 989 per cent. This gain was more than twice the increase in production in steel ingots which amounted to 442 per cent between 1932 and 1940.

Nearly 5 pounds of welding wire were produced last year for each net ton of finished steel produced, compared with 2.6 pounds in 1932.

National
Carbide



DEPENDABLE

EFFICIENT

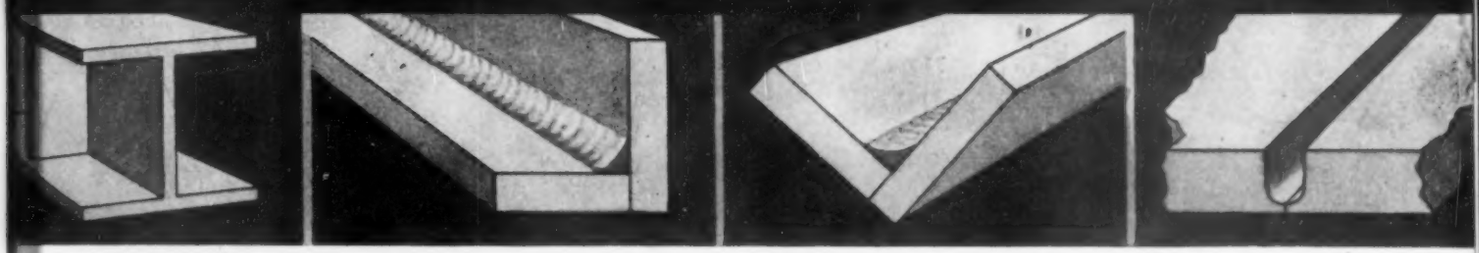
ECONOMICAL

FOR WELDING and CUTTING
Use National Carbide in the Red Drum
NATIONAL CARBIDE CORPORATION
Lincoln Building New York, N. Y.

Here's where you can work wonders with A-C WELDING!

WHILE not a cure-all, a-c welding *has* helped many operations that were hard-pressed to show a satisfactory profit. Countless shops, desiring higher speeds than they were getting with d-c, have changed over to a-c with very profitable results in reduced production time and improved welds.

INCREASE YOUR PRODUCTION AND PROFIT ON JOINTS LIKE THESE



Welding In Corners — where magnetic blow prevails—reworks and rejects of unsound welds caused by magnetic blow are reduced to the minimum with a-c welding. The use of higher currents and larger electrodes on work like this also results in faster welding.

On Horizontal Fillets, welding speeds can be increased 15 to 30 per cent, especially on currents above 200 amp. One shop, for example, was producing 11 linear feet of $\frac{5}{16}$-in. horizontal fillets per hour, using d-c welders and $\frac{5}{16}$-in. rods. After changing to a-c, welding current was successfully increased to permit use of $\frac{1}{4}$-in. electrodes, and *15* ft. of welded joint were produced per hour. A-c welding, in this case, increased production speed 36 per cent.

Flat Fillets—On this type of joint where high travel speeds are possible with the aid of high-melting-rate electrodes and heavy currents, the elimination of *magnetic blow*, by means of a-c welding with its easily controlled arc, permits the use of the maximum currents and largest electrodes your work can stand.

If You Weld Deep-groove Butt Joints, where large electrodes, high deposition rates and thorough penetration are paramount factors, a-c welding offers many advantages in speed and finished quality that are impossible to obtain with d-c. The uniform, sound welds obtained with a-c on this type of work are readily indicated by an improved appearance and are *proved* by testing and X-ray inspection.

If your work includes any or all of the types of joints illustrated above, there's a good possibility that a-c welding can be applied to your operations with *an extra profit for you.*

Your nearest G-E arc welding distributor will be glad to demonstrate a-c welding on your work—no obligation. His recommendations will be unbiased, *based only on what will give best results.* He can do this because he carries the G-E line of welders—the most complete line of welders on the market.

For complete and *reliable* information—see your G-E arc welding distributor or G-E office today. If you prefer, write direct to General Electric, Schenectady, New York.

GENERAL ELECTRIC

972-32-6748

New 300-amp a-c welder, transformer type, similar to the 500-amp size. Running gear for portability is available.

WELDING IN BRAKE AND CLUTCH LININGS

No screws or rivets are used for installing linings in the brakes or clutches built into the earth moving equipment manufactured by R. G. LeTourneau Co. of Georgia. They use a special lining with $^1/_{16}$-in. steel backing, the lining being cut back from the edges of the steel for about $^1/_{16}$ in. to permit easy welding.

Courtesy Hobart Bros. Co.

The drawing above shows how tack welds about $^3/_8$ in. long are spaced about 1 in. apart in a typical brake band lining job, the metallic backed lining being clamped to the band with C-clamps during the welding operation. The spaces between lining sections are to compensate for expansion and contraction.

Advantages claimed for this method are:

1. Machine shop labor saved—no drilling or tapping.
2. Linings fit perfectly at all times.
3. No screws or rivets to work loose in service.
4. No chance for scoring of brake drums or clutches.

TUBE DATA CHART

A chart just completed by the Steel and Tubes Division of Republic Steel Corporation makes available in conveniently abbreviated form a useful compilation of electric resistance welded tube data on sizes, tolerances, weights per foot, chemical analyses and physical properties of round tubing and also squares and rectangles.

Source of the technical information is a handbook in which for years Steel and Tubes has incorporated all essential data used by purchasers of mechanical steel tubing such as the company manufactures.

Compact enough (22 x 14 in.) to be hung on the wall or placed under the glass top of a desk, the chart is the result of an effort to make such information more readily available to the engineer who today is working under the high pressure of the national defense emergency to lay out a part or write a specification in a minimum of time.

Data contained in the chart is *standard* for the welded steel tube industry and has been organized in such a fashion that the user can tell at a glance exactly what standard size, analysis, etc., of steel tubing, with tolerances that are also standard, will fill the requirements.

Entitled "Engineering Data on Electric Resistance Welded Steel Tubing," copies of the chart will be available upon request to all who can use them to advantage, it is announced by the company.

M. R. DILL DIRECTOR OF LINCOLN ELECTRIC COMPANY

The Lincoln Electric Company, manufacturers of arc-welding equipment, Cleveland, Ohio, announced the election of M. R. Dill as a director at its recent annual meeting of shareholders. Mr. Dill was also elected general counsel at the last meeting of the Board of Directors.

Mr. Dill graduated from Lakewood High School in 1925 and attended the Wharton School of the University of Pennsylvania for his pre-law education. He graduated from the Law School of Ohio State University in 1930 and immediately became associated with the well-known law firm of Squire, Sanders and Dempsey, Cleveland, Ohio. During his college career he took an active part in athletics, was on the varsity football team, and was a member of Sigma Chi and Phi Delta Phi Legal fraternity. Mr. Dill is Vice-President of the National Alumni Association of Ohio State University and a member of the Hermit Club of Cleveland.

Directors and officers who were re-elected include: J. C. Lincoln, Chairman of the Board of directors; J. F. Lincoln, President and General Manager; C. M. Taylor, Vice-President; A. F. Davis, Vice-President and Secretary; G. G. Landis, Chief Engineer; Harold F. Kneen, Plant Superintendent; J. W. Meriam and W. B. Stewart.

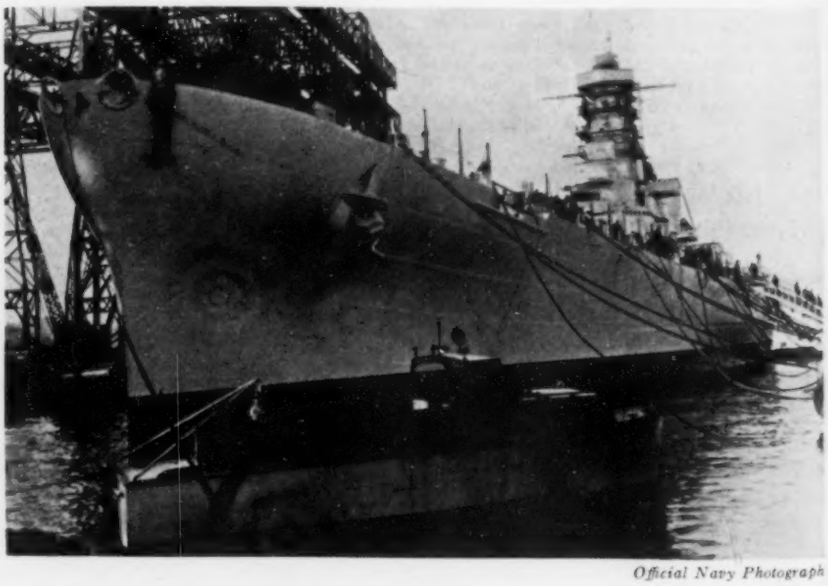
MOORE REPRESENTATIVE

Mr. J. D. Cunningham, formerly with The Lincoln Electric Company in San Francisco, California, has just been made the manager of the Welding Division of the Moore Machinery Company, who cover California, Arizona and Nevada on all arc-welding and gas-welding supplies. The Moore Machinery Company are exclusive agents for the Westinghouse Electric & Manufacturing Company.

Mr. Cunningham's record in the welding field of the West is well known; graduating from the University of California in 1932, he traveled to Boulder Dam where he was employed by the Babcock-Wilcox Company in the Metallurgical Laboratories there. He left that company to go with the Bureau of Reclamation as welding engineer in charge of the welding of the pit liners at the turbine bases for Boulder Dam. His job here also entailed the setting of the large water wheels on level and various mechanical engineering jobs in and around the Dam site. From there he was taken to Los Angeles by the Western Pipe & Steel Company where he handled the X-ray and stress-relieving operations for them on the Metropolitan Water District Pipe Line job, along with this, qualifying and handling the testing of all welders for the job. He has also been employed as a Consulting Engineer.

WORLD'S MIGHTIEST SHIP IS OF ARC WELDED CONSTRUCTION

The welding industry is eyeing with pride the United States Navy's mightiest fighting ship, the 35,000-ton, $70,000,000 U.S.S. *North Carolina*. Arc welding was used to a great extent in the construction of the hull, and all portholes have been omitted, greatly simplifying her construction and increasing the strength of her frame. This mighty ship carries nine 16-inch guns. Eight Hobart arc welders are installed aboard the battleship for maintenance and machine shop work.



Official Navy Photograph

GOOD NEWS!

FOR USERS OF RESISTANCE WELDING

SWEEPING PRICE REDUCTIONS ON IGNITRON TUBES

As a result of wide-spread acceptance and increased use, we announce a reduction in prices on our improved line of stainless-steel ignitron tubes, effective immediately.

With both inner and outer shell of corrosion-proof steel, G-E ignitron tubes offer resistance-welding users greater economies and performance capacity than ever before.

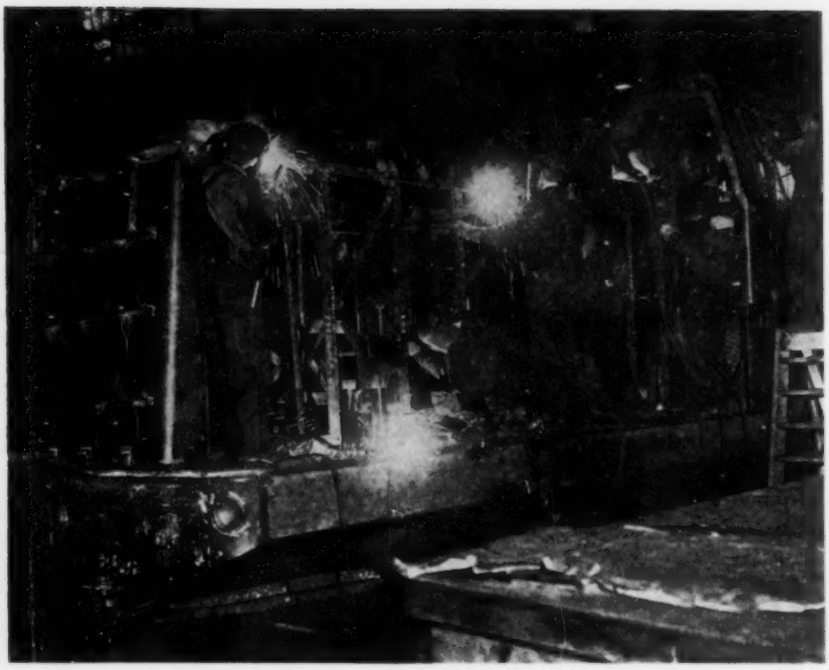
Full information on how these tubes can help improve your welding profits is readily available from our local office. Or write to General Electric, Schenectady, N. Y.

Types	Old Price	New Price
FG-258A	$295	$250
FG-235A	$140	$110
FG-271	$75	$55

1941
Type FG-271 All-metal
New low price $55
Demand current,
10% duty cycle = 830 amp

1936
Type FG-179 Glass
Price $290
Demand current,
10% duty cycle = 560 amp

GENERAL ELECTRIC



Welding Switching Locomotive Frame

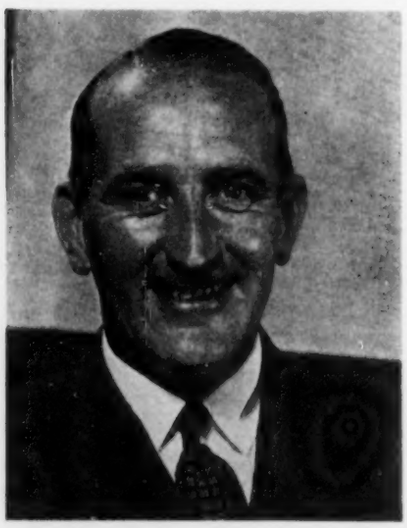
SWITCHING LOCOMOTIVE

Soon to take its place in America's defense preparation line is this switching locomotive frame being hustled along to completion by skilled welders in the Erie, Pa., works of the General Electric Company.

When completed, the 80-ton, 500-horsepower, Diesel-electric switcher will go to work in one of the big steel companies, hauling steel for vital defense needs.

J. R. SPENCE MADE GENERAL SALES MANAGER OF STOODY COMPANY

Mr. J. R. Spence, better known to his friends as "Jack," has recently been appointed General Sales Manager of Stoody Company. Jack has been active in the hard-facing industry for many years and is not only responsible for the development of several hard-facing alloys but has also been instrumental in determining correct procedures for hard-facing many types of industrial equipment.



Mr. Spence has been with Stoody Company more than six years, serving first as Chief Metallurgist and later as Industrial Sales and Research Manager.

VICTOR EXPANDS PRODUCTION FACILITIES

The unprecedented increase in demand for welding and cutting equipment and supplies again made it necessary for Victor Equipment Company to enlarge its San Francisco Welding Division plant. Approximately 11,000 square feet of production and warehouse space were added and the management's foresight in buying numerous new and modern production tools early made it possible to receive delivery of most of these new tools.

The plant now operates on a 24-hour basis and while production still lags considerably behind orders received, the company expects that these new facilities will be more adequate to assure shipment with greater promptness.

The company's Los Angeles plant also will be augmented and certain overflow items will be manufactured at that point.

SOUTHERN OXYGEN COMPANY BECOME VICTOR DISTRIBUTORS

Victor Equipment Company with headquarters at 844–54 Folsom Street, San Francisco, California, announces that they have recently appointed the Southern Oxygen Company, with headquarters at Arlington, Virginia, as exclusive Victor welding and cutting apparatus distributors covering the states of Virginia, Maryland and North Carolina, and certain portions of Kentucky and Tennessee. The Southern Oxygen Company is an old established producer of oxygen, acetylene, hydrogen and other gases, and they are actively engaged in both the welding and cutting industry and in the distribution of medicinal gases and equipment. This company maintains over 45 offices and warehouse branches and is therefore particularly well situated to facilitate prompt shipments.

UNION CARBIDE OFFICERS

Directors of the Union Carbide and Carbon Corporation at a meeting held here today elected Jesse J. Ricks, formerly president of the corporation, as chairman of the board. Benjamin O'Shea, formerly vice-president, was named as the new president.

At the same meeting James A. Rafferty, a vice-president, was elected to the board of directors to fill the vacancy caused by the resignation of Matthew J. Carney. Robert W. White, secretary and treasurer, was made a vice-president as well.

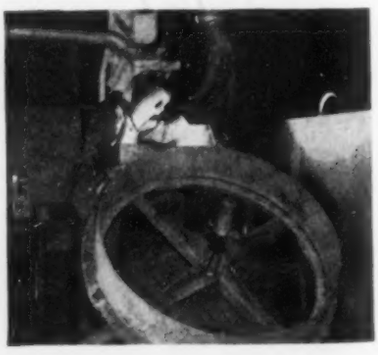
Since the death in 1937 of C. K. G. Billings, the last chairman of the board, the duties of chairman and president had been consolidated in the presidency.

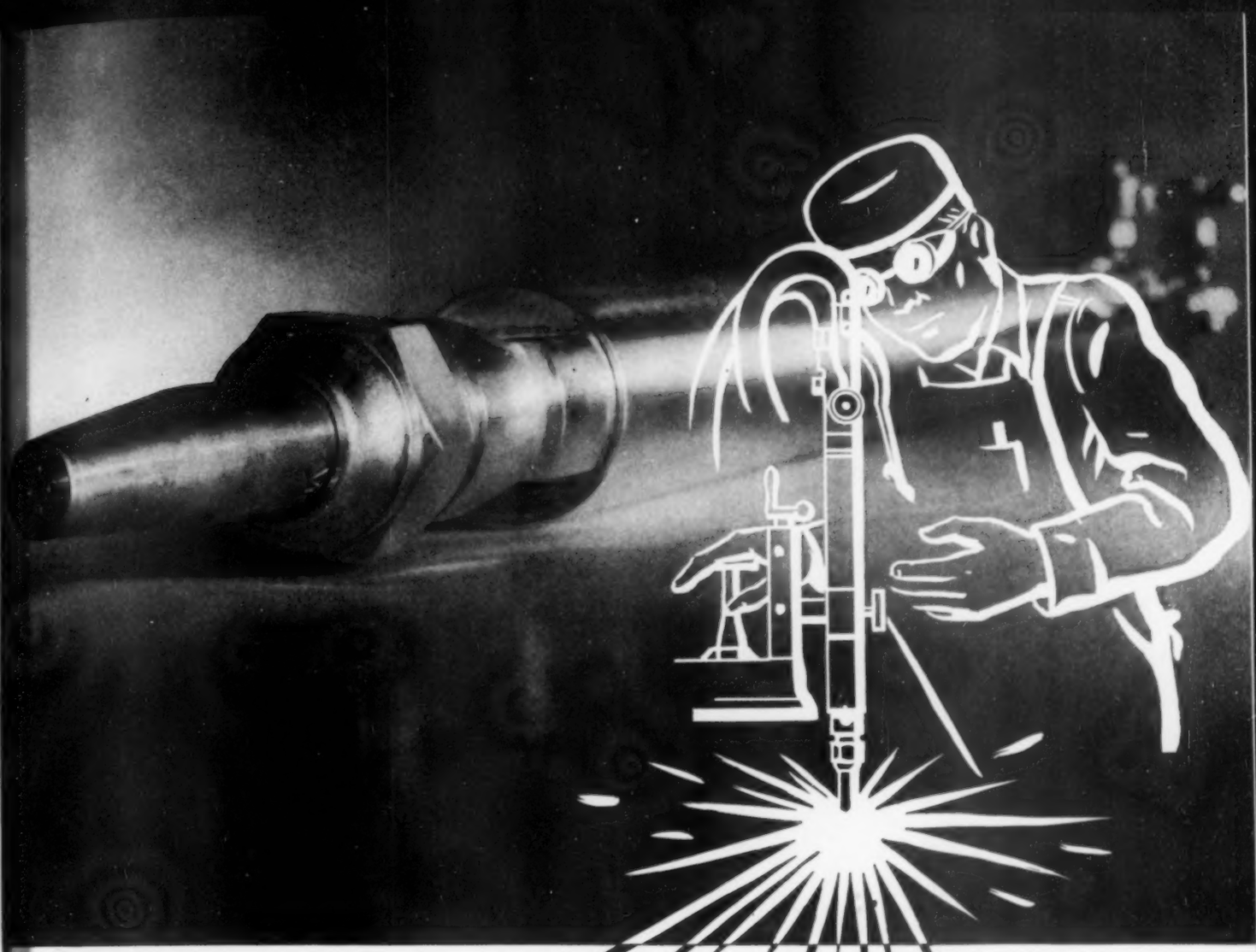
Both the new chairman and the new president have been associated with the corporation since its formation in 1917. Mr. Ricks was one of the leaders in its creation and served as vice-president until 1925 when he was elected president. Mr. O'Shea, who was elected a vice-president in 1925, came to the corporation as an executive of the Union Carbide Company, which was acquired by Union Carbide and Carbon Corporation in 1917, and with which he had up to then spent his entire business career.

These moves, it is stated, will in no way change any policies or programs of the corporation.

HEALTH OF WELDING OPERATORS

To eliminate any possible hazard from weld fumes in the huge Harnischfeger plant in Milwaukee, a system of fume collectors has been installed. The individual collector units are adjustable to any position and so may be spotted by the welder where they can most effectively draw off the fumes and gases. Because they draw off only a minimum amount of surrounding air, these collectors are economical even for winter use.





VICTOR

COSTS LESS TO OWN AND OPERATE

Now, more than ever before, excellence in tool design is imperative when our national need for production speed calls for maximum economy of time and raw materials.

It is no small wonder then that the acknowledged excellence of VICTOR welding and cutting equipment has caused an unprecedented increase in demand. We have again doubled our plant capacity, and can assure our thousands of customers from Coast to Coast that we will leave nothing undone to speed up shipments of tools so vitally needed in our National Armament Progam.

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IN CANADA: Hollup Corporation, Ltd., 107 Atlantic Avenue, Toronto

NEW PRODUCTS

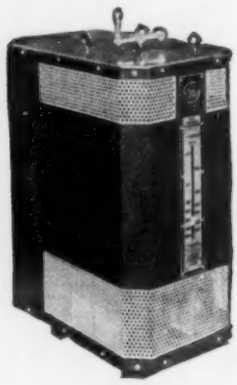
The Society assumes no responsibility for the validity of claims in this Section

ATOMIC-HYDROGEN ARC WELDERS

General Electric 35- and 75-ampere atomic-hydrogen arc welders of improved design at prices reduced approximately 15 per cent have recently been made available, according to C. I. MacGuffie, manager of G-E electric welding sales. Atomic-hydrogen welders are finding increasing use in industry for repairing tools and dies; for filling in flaws or blow-holes in steel and bronze castings; and for the fabrication and repair of hard-to-weld metals.

Modern in design, the new welders are compact and self-contained to reduce space requirements and for increased portability and pleasing appearance.

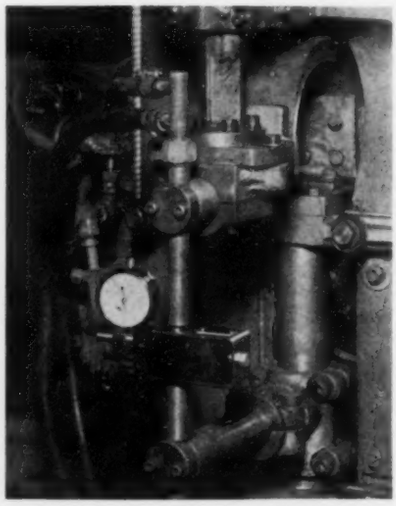
Instead of the transformer and reactor used in previous units, the new welder has a specially designed reactive transformer which combines the functions of both the transformer and reactor. As a result, the weight of the welder has been reduced more than 30 per cent, and electrical characteristics improved.



Built-in power-factor correction, a feature of the new welders, helps to reduce installation cost and avoid power-factor penalties. Fan-forced ventilation provides cool operation, even at high currents or on high duty cycles.

ELECTRODE PRESSURE GAGE

An electrode pressure gage designed to measure the pressure between the electrodes of resistance-welding machines has been announced by the General Electric Company. The gage is for use either as a standard for checking existing gages or pressure indicators on spot, line or projection welders, or for checking the electrode pressure at the time of set-up, before proceeding with production work. It also may be used by testing laboratories for pressure determinations, or by industrials interested in checking the pressure of various kinds of springs in compression.



G-E Electrode Pressure Gage Mounted Between Electrodes of Resistance Welding Machine

The new gage measures pressures from 0 to 4500 lb.; an automatic stop safeguards it against damage, should pressures of more than 4500 lb. be applied. Consisting simply of a calibrated steel yoke and a micrometer dial indicator, the gage is easily applicable to existing resistance welding machines without the need for jigs or other auxiliary equipment.

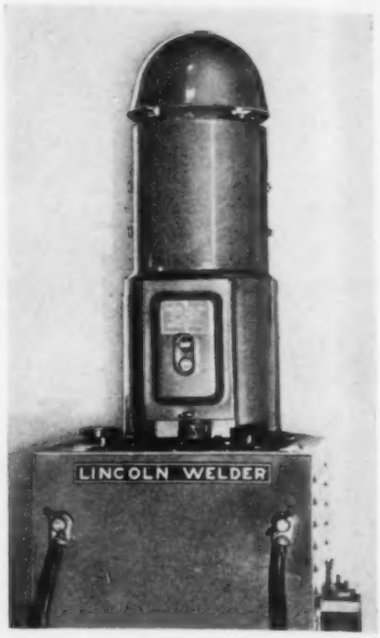
When electrode pressures are to be measured preliminary to production work, the gage is inserted between the electrodes so that they press on the pads on the top and bottom of the gage yoke. The electrode pressure is adjusted until the desired pressure is registered on the gage dial. The gage is then withdrawn and the welding machine placed in operation.

The dial indicator is direct reading; no calibration curves or multipliers are necessary. It has two scales, one for reading in 10-lb. intervals up to 1000 lb., and the other to read in 1000-lb. intervals. Each gage is carefully calibrated at the factory before shipment.

AIRCRAFT ARC WELDER

A new arc-welding machine, which is designed particularly for airplane welding, and which was developed for the express purpose of aiding aircraft production for National Defense, is announced by The Lincoln Electric Co., Cleveland, Ohio.

Most important of the features which adapt this new welder specifically for aircraft work is its system of welding current and voltage control. This feature is of particular importance because it permits the finely accurate settings which are essential for welding the particular analyses and gages of metal employed in modern plane construction.



Adjustable in a continuous sequence of fine increments, the control avoids the compromise settings of conventional welding current controls which sacrifice welding speed or weld quality, or both.

The aircraft arc welder is available in 2 models, 150- and 200-ampere sizes, either portable or stationary. Current range for the 150-ampere model is 10 to 200 amperes and for the 200-ampere model 10 to 250 amperes.

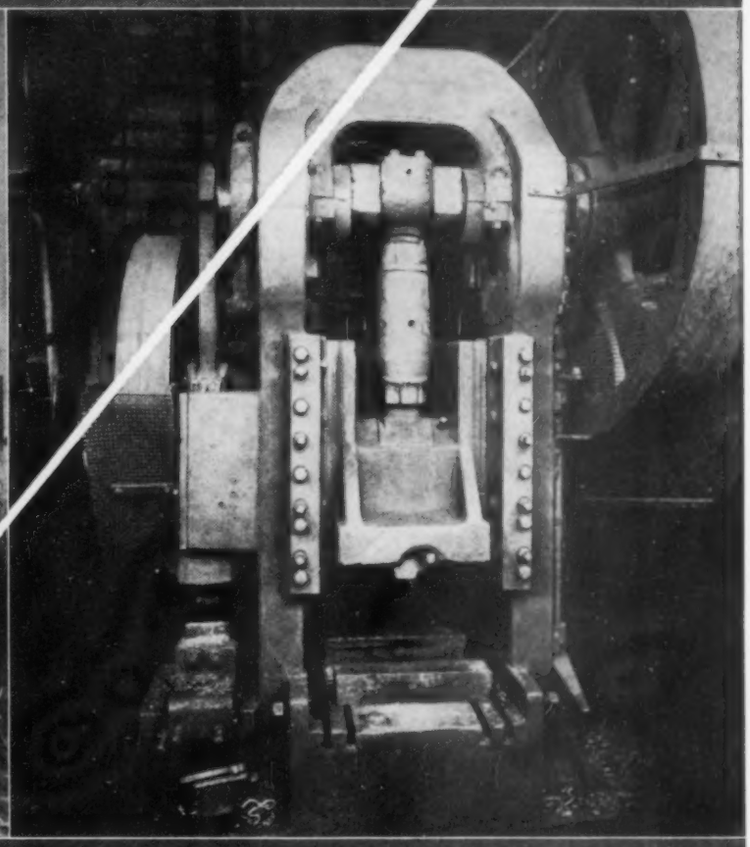
IMPULSE TIMERS

Frequently conditions are encountered in resistance welding, where a single "shot"—for various reasons—will not produce a perfect or consistently satisfactory weld. To meet such conditions, a line of electronic "impulse" timers is now available from Weltronic Corporation, 3080 E. Outer Drive, Detroit. The line consists of a semi-automatic (Model No. 114) and a high-speed automatic (Model No. 57) Weltronic timer.

The semi-automatic timer is adjustable for "on" time, "weld" time, "cool" time, and for the number of interruptions of current desired. The high-speed automatic, in addition to these adjustments, also has a dial for regulating the "off" time between resistance welds.

With these timers welding operations, extremely difficult heretofore, can now be made with ease. This is particularly true for the welding of relatively heavy sections such as are found in structural work, automobile frames, truck cabs, blowers, farm implements, etc. In the other direction, they simplify the welding of large numbers of laminated metal sections. For instance, as many as 15 or 20 pieces of No. 20 gage can be welded together at one time through the use of these timers.

FROM THIS — TO THIS



IN 46 HOURS!

Thanks to Anaconda 997 Low Fuming Welding Rod

WHEN the Hebeler Welding Company of Buffalo, New York, were called in on this emergency job, they took one look at the fractured 4½-ton punch press; promptly recommended repair welding with Anaconda 997 Low Fuming Rod . . . a high strength, tough weld metal with low fuming characteristics.

The job consumed 160 pounds of filler rod and 1,600 feet of both oxygen and acetylene. Chipping, preheating with natural gas and compressed air and other preparation required 35 hours; welding, 11 hours. The result was a strong sound weld and a happy production manager, for the downtime loss was only a fraction of what he expected.

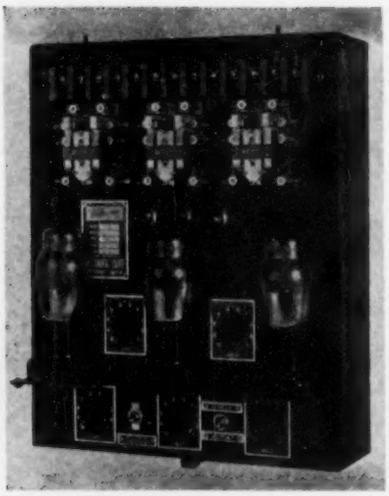
Next time you're faced with a similar emergency, bear this story in mind. Anaconda Rods are produced in an extensive line of alloys for all kinds of welding. You can obtain them from your jobber. 40119

ANACONDA from mine to consumer

Anaconda Welding Rods

THE AMERICAN BRASS COMPANY, General Offices: Waterbury, Connecticut

In Canada: Anaconda American Brass Ltd., New Toronto, Ont. • Subsidiary of Anaconda Copper Mining Company



The reason such welds are now possible is that the interruptions of current give the points a chance to cool off, while at the same time pressure between the points squeezes the metal parts together to form a better contact and more perfect weld.

NEW CAPACITOR DISCHARGE RESISTANCE WELDING CONTROL

For welding aluminum and alloys such as are used in the aircraft industry, a new capacitor discharge resistance welding control is announced by Westinghouse Electric and Manufacturing Company.

Known as the Condens-O-Weld, this unit is a complete control designed to include in one floor mounted cabinet all the necessary apparatus required to control an electrostatic energy storage type of welder.

The Condens-O-Weld is designed for operation on 230/460 volts ± 10 per cent, 3 phase, 50 or 60 cycles. The charging circuit and its control charges a 2640 mfd. capacitor bank to 3000 volts. Spot-welding speeds of 40 to 80 spots per minute are obtained depending on the size of capacitor bank.

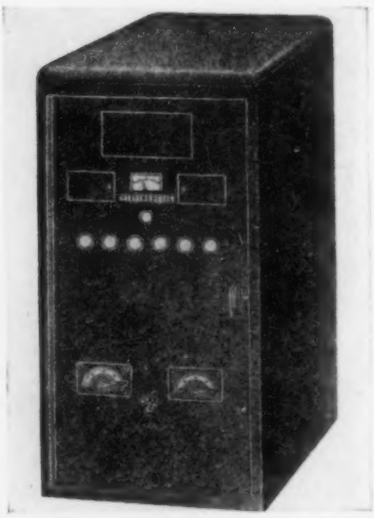


Fig. 1—Closed, Dead Front View of Westinghouse Type CD-2 Capacitor Discharge Welding Control Showing Balanced Design, Accessibility of Controls

Charging the capacitor may be taking place during the entire time interval between successive welds, thus reducing the power demand to a minimum. When used with certain welding machines, line kva. demands as low as $^1/_{10}$ of that taken by a typical single phase a.-c. aluminum welder are possible.

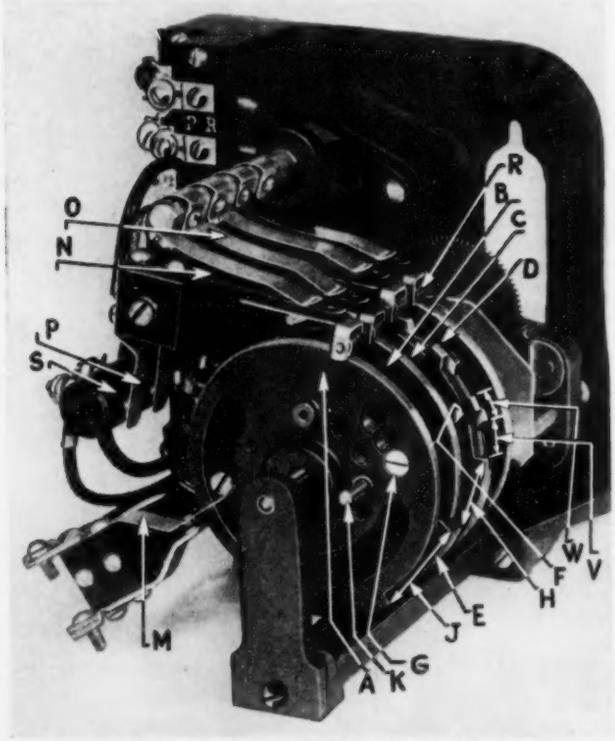
SEAM AND SPOT WELDING TECHNIQUE

Useful information on the technique of seam and spot welding is given in a new 4-page leaflet announced by Westinghouse Electric and Manufacturing Company.

Factors affecting pressure, current and timing are discussed with special emphasis on time of current flow. Synchronous and non-synchronous control applications are treated with recommendations for the proper use of each system.

Specifications for aluminum and brass welding are given. Tables list data on seam welding of mild pickled and oiled steel, spot and projection welding.

A copy of descriptive data 18-333 may be secured from department 7-N-20, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.



National Type #1540P to #1549P Series Weld-Timer.

IT'S A GOOD PLAN

TO PUMP THE HEAT THROUGH Your SPOT WELDED JOINTS

National Interrupted Weld Timers

Prevent Burns
Eliminate Flash Marks
Double Electrode Life
Reduce Current Consumption

Even on Ordinary Automobile Body Sheets, CHEVROLET has found This Timer Highly Satisfactory.

At the same time, you have no difficulty Welding metal, ½" thick overall, without increasing Transformer Size. The timer, illustrated at the left, is arranged to control both pressure to electrodes, as well as the weld, after Pressure has been applied. These timers are daily Attracting NEW CUSTOMERS, while OLD USERS still send in REPEAT ORDERS. NATIONAL makes friends, and Keeps them —because it does such a good job—in such a simple manner. There are No Mystery Circuits, Tubes and Gadgets. Everything is in Plain View, and easily Adjustable. Cam D (with notches) interrupts the weld circuit, any where from one to 7 times, on each weld. It holds the critical 'off-time' between charges down to about one cycle. This is the Real Secret of Interrupted Spot Welding.

Write for our New Bulletin #146

NATIONAL TIME & SIGNAL CORPORATION

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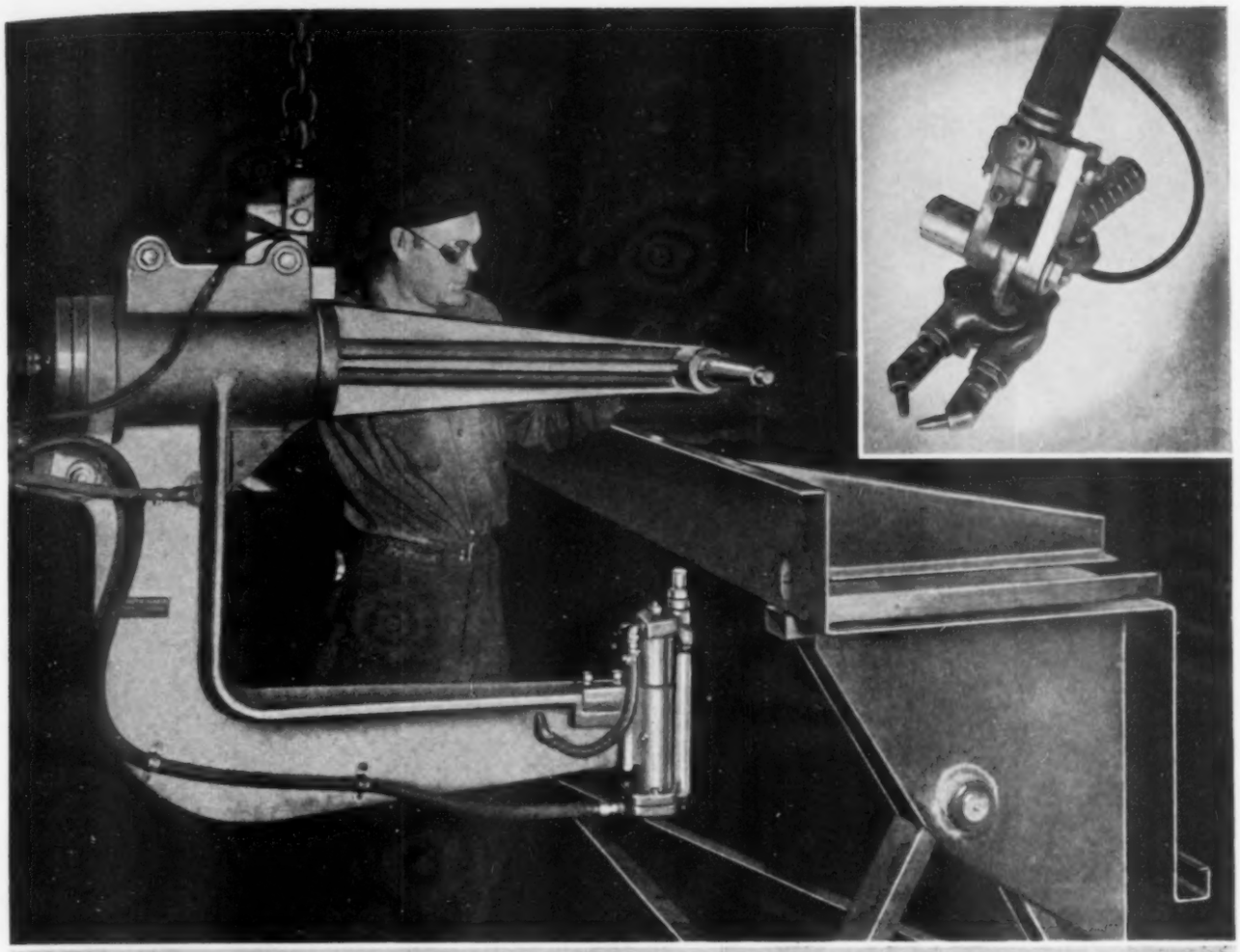

GUNS *behind the lines*

Guns to build planes—guns to build plants—guns for tanks and trucks—guns for the myriad of items needed for national defense from ammunition boxes to soup kitchens.

To see that resistance welding guns—the "guns behind the lines" are available for whatever purpose they may be needed: to speed production, to simplify manufacture, to cut costs—and as fast as needed—is Progressive Welder's business.

ILLUSTRATED ABOVE

Swivel construction of the upper electrode in this Standard Progressive "C" type gun enables clearing of obstructions in welding formed steel sections. (Available with long or short throats, without swivel feature, etc.) Insert shows a standard Progressive gun for lighter work—featuring self-locking full swiveling action, single pin cable clamp and P-H flexible kickless welding cable. There are several hundred 'standard' and semi-standard guns in the Progressive line—pinch guns, push guns, expansion guns, etc.

Today, with a new plant providing ample manufacturing facilities Progressive is able to fill all indicated needs for portable welding guns. Furthermore, there is a standard Progressive gun for virtually every conceivable job, large or small—from inch sections to light gauge aluminum and stainless—cutting design costs and delivery time. Your blueprint will bring you a quotation virtually by return mail. Write or wire direct to our main office or the following:

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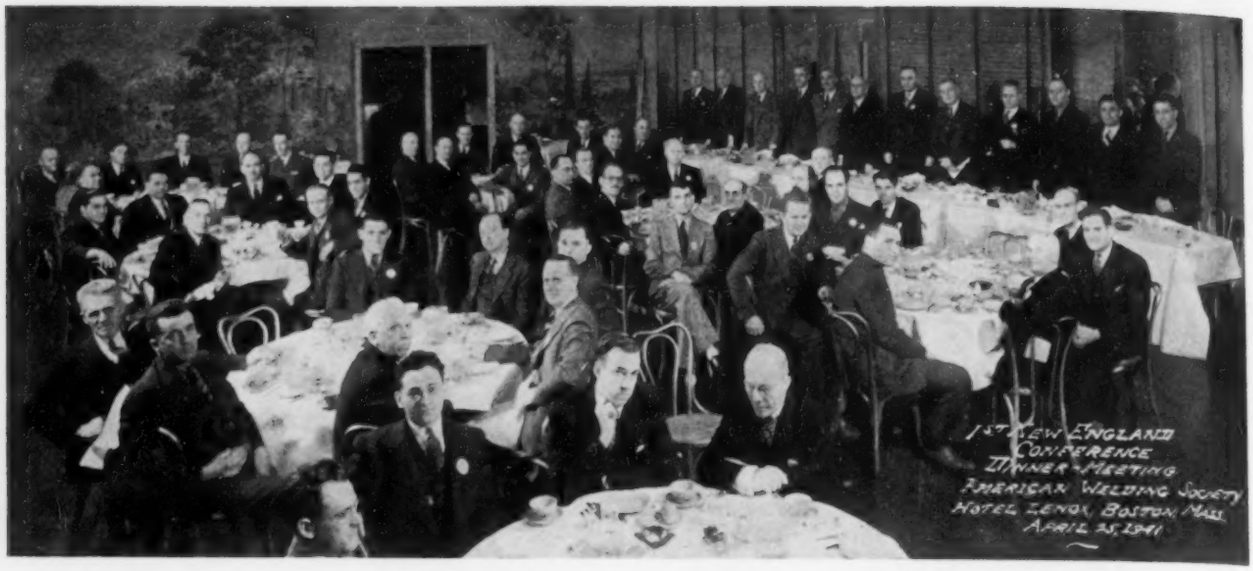

SECTION ACTIVITIES

BOSTON

Mr. L. F. Jackson, Past-Chairman of the Boston Section, has been elected President of the Engineering Societies of New England, Inc., of which the Boston Section is a member. Mr. Jackson assumed the office of President June 3rd.

CHICAGO

The following are the newly elected officers and directors of the Chicago Section for 1941–42:

Chairman, A. M. Unger, Pullman Standard Car Mfg. Co.; *Vice-Chairman*, Eric R. Seabloom, Crane Company; *Secretary-Treasurer*, M. S. Hendricks, *The Welding Engineer*. *Directors for three years:* L. C. Monroe, H. M. Downing, C. L. Pfeiffer, E. P. Everhard. *Director-at-large:* C. J. McGregor. *Directors:* (term expires in 1 year) H. P. Guirl, L. G. Pickhaver, C. J. Daniels, R. L. Kohlbry; (term expires in 2 years) Tom Harle, H. J. Kicherer, J. H. Hruska, C. D. Young.

One hundred one golfers participated Saturday, June 21st, for prizes in the Chicago Section Third Annual Golf Tournament held this year at Big Oaks on the northwest side of Chicago. Despite the 91° temperature, the ball chasers turned in some excellent scores and reported an excellent day's outing and general good time. Some of the Milwaukee Section members were on hand to spend the day with their Chicago confreres.

After the scores had been turned in and handicaps figured, 95 members and their guests for the day sat down to a steak dinner and waited with whatever patience they could muster to find out if they were among the fortunate ones to have a share of the 35 prizes.

The complete list of prize winners is too lengthy to record, but those who came away with the cups should have their accomplishments as golfers recorded for posterity. The Chicago Section Cup, the permanent possession of which goes to the member winning it three times, was won for the second time by William Munro, The Bastian-Blessing Trophy was awarded to W. Ferguson, while the feature prize of Chicago Section tournaments—the chromium special cup—was awarded to L. Matis with the high gross score. A special prize for Milwaukee Section members went to Bill Hart.

This year's tournament was under the general chairmanship of Russ Long, Hollup Corporation. Assisting him were Harold Zeigler, National Cylinder Gas Company, in charge of arrangements and prizes, Bill Browning, The Linde Air Products Company, heading the Grounds Committee and Ted Jefferson, The Welding Engineer, handling publicity.

NORTHERN NEW JERSEY

The annual meeting of the Northern New Jersey Section was held at the Essex House, Newark, on May 20th. The first speaker of the evening was Comfort A. Adams, who delivered a fine inspirational talk on the history of the AMERICAN WELDING SOCIETY and the significance of its activities in the various fields of welding research. Dr. Adams was followed by Joseph W. Meadowcroft, Assistant Works Superintendent of the Edward G. Budd Manufacturing Company, Philadelphia. Mr. Meadowcroft gave a brief outline of his use of the various welding processes, from the early days when each user had to generate his own oxygen by chemical processes, up to the present time when all of the welding methods have been developed to a high degree.

In the business session of the meeting, announcement was made of the election of officers and Executive Committee for the coming year as follows:

Chairman, F. C. Fyke, Standard Oil Development Co; *Vice-Chairman*, E. F. Humm, Chicago Bridge & Iron Co.; *Secretary-Treasurer*, H. S. Card. *Executive Committee:* (term 1 year) H. H. Troger, Jr., G. C. Holder, P. A. Salmon; (term 2 years) G. W. Nigh, R. E. Powell, G. J. Blind.

Chairman Fyke called attention to the excellent work done by the Membership Committee which had resulted in a rate of growth in the Northern New Jersey Section several times as large as that of the SOCIETY as a whole. He also praised the work of the Program Committee, the Exhibit Committee and the Outing Committee. Announcement was made at this time that a Summer Outing will be held by the Section on Saturday, September 6th. After adjournment of the formal meeting, members and guests enjoyed a social hour with refreshments.

NORTHWEST

The Northwest Section held its fourth annual meeting Wednesday, May 21st, at which the following officers and members of the executive committee were elected:

Chairman: J. H. Barron, Sales Manager, Stainless & Steel Products Co., St. Paul.

Vice-Chairman: C. E. Comfort, Shop Superintendent, St. Paul Structural Steel Co., St. Paul.

Secretary-Treasurer: Alexis Caswell, Secretary, Manufacturers' Association of Minneapolis, Inc.

Executive Committee: Floyd O. Borne, Associate Engineer, U. S. Engineers, St. Paul; E. E. Hall, Superintendent, Flour City Welding Co., Minneapolis; T. P. Hughes, Assistant Professor of Mechanical Engineering, University of Minnesota, Minneapolis; Louis T. Kenny, President, Kenny Boiler & Mfg. Co., St. Paul; John Mikulak, Mechanical Engineer, Electric

More and more, the country accepts a new order in industrial buying and selling as the defense program speeds up. In the electric welding industry an annual production rate of 275,000,000 pounds of electrodes (approximately double that of 1940) is still not enough to meet requirements.

In spite of increased production facilities—our own new plant at East Chicago, for example, has increased our capacity 50% and is soon to be stepped up to still greater output—it is practically impossible for most electrode suppliers to maintain normal deliveries.

Priorities, metal and material shortage, bottlenecks in the production of the machinery for manufacturing electrodes—are not alibies—they are the hard facts with which the entire electrode industry is faced.

May we suggest, therefore, that ***you order electrodes when you order your steel.*** By thus ordering promptly, you can be more certain of having electrodes on hand with which to start work when the steel is received.

And if you need greater production on welded products, remember, the Murex engineering department is available for consultation as to ways and means of speeding up welding and reducing costs.

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MUREX HEAVY COATED ELECTRODES

THERMIT WELDING — STANDARD FOR 40 YEARS FOR WELDING RAILS AND HEAVY EQUIPMENT

Machinery Mfg. Co., Minneapolis; R. W. Robinson, Manager, American Bridge Company, Minneapolis; R. L. Spaulding, Foreman, American Hoist & Derrick Co., St. Paul; T. J. Warmington, Plant Manager, Wm. Bros. Boiler & Mfg. Co., Minneapolis.

Brief reports by the officers showed a larger membership than at the last annual meeting and a constantly increasing interest in the activities of the Section.

Magician Gordien disclosed some of his bag of tricks for the entertainment of those present.

The speaker of the evening was F. L. Plummer, Chief Research Engineer of the Hammond Iron Works, Warren, Pa., who presented a most interesting discussion of his subject, "Welding Applied to Structural Buildings and Bridges," which was illustrated by lantern slides.

OKLAHOMA CITY

The Oklahoma City Section held its regular meeting May 8th at the Biltmore Hotel. The speaker was Mr. C. W. Metzger of the Haynes Stellite Company of Houston, Texas. Mr. Metzger's address had to do with the various types of hard facing materials and their particular applications. The talk was preceded by a motion picture on this subject.

The Section was very fortunate in having a visit from the President of the Society, Colonel G. F. Jenks. A special meeting was arranged for the night of Friday, May 16th. Approximately 85 members and guests were present. Colonel Jenks spoke on the subject, "Welding in National Defense," and his talk was accompanied by slides. Considerable interest was displayed by the members present regarding the subject matter of this address.

The following are the results of the election of officers for the 1941–42 season: *Chairman*, C. C. Willis, Oklahoma Gas & Electric Co.; *Vice-Chairman*, Francis Sprehe, Midwest Steel Co.; *Secretary*, William T. Tiffin, University of Oklahoma; *Treasurer*, W. D. Brewer, Oklahoma Gas & Electric Co. *Executive Committee:* (term 2 years) K. B. Banks, J. M. Mideke, W. H. Rice, M. G. Wicker.

PHILADELPHIA

In place of its regular meeting, the Philadelphia Section held a get-together and organization meeting on Monday, May 19th, at the Philadelphia Country Club, located in a very delightful spot in the Philadelphia suburbs. Dinner was attended by over sixty persons, with a good proportion of ladies.

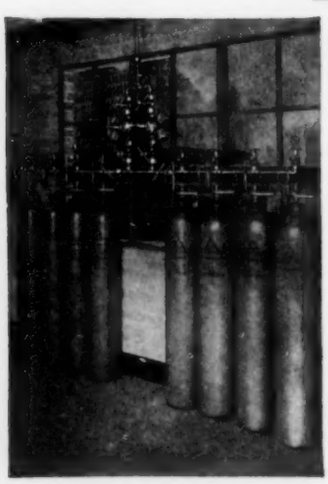
The primary purpose of the meeting was to afford those who are to take an active part in the 1941 meeting arrangements an opportunity to get acquainted and to learn something about the work confronting them.

After cocktails, a delicious dinner was served on the veranda of the club. Following the dinner, Mr. Barnes, Vice-Chairman of the Convention Committee, and in charge of local arrangements for the annual meeting, opened the meeting with a few words of welcome and appreciation for the splendid response to his invitation to the dinner. There were read notes of regret from the Chairman of the Convention Committee and the Secretary of the Programs Committee, both of whom were unable to be present because of their attendance at the Western Metals Congress.

Mr. Barnes then called upon Dr. Adams, Founder and First President of the SOCIETY, to review for the benefit of the newer members present some of the SOCIETY's background and its accomplishments over the 22 years of its existence. He then presented the retiring Chairman; the newly elected officers of the Philadelphia Section, and Miss M. M. Kelly, the National Secretary, who, in behalf of the SOCIETY membership and herself, expressed deep gratitude to the Philadelphia Section officers and members who are giving so generously of their time and effort toward making the 1941 annual meeting an outstanding affair.

The Chairman of the New York and York Sections and the various committees on arrangements for the annual meeting were requested to say a few words and finally Mr. Barnes introduced the Chair-

For SAFETY SPEED ECONOMY



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Pioneers and Manufacturers of Precision Equipment for Using and Controlling High Pressure Gases

The Operator Says:
"Mallory Tips cut down redressing...and thanks to standardization replacement is a cinch when it is needed."

The man "on the line" does not applaud performance unless it is earned the hard way. That's why Mallory is proud of the reputation Mallory Welding Electrodes enjoy among welding machine operators.

No other manufacturer has approached the investment Mallory has made in its program of standardization . . . but it has been more than justified by the unassailable position of leadership it has won. Mallory Welding Electrodes are definitely better because of standardization. Limitless field experience has definitely established the specific requirements of cooling, design, hardness, electrical and thermal conductivity for each purpose. The result is more welds between redressing . . . and a far greater number of welds between replacements. Standardization has also eliminated costly delays while special orders are being completed. Specify Mallory and save in every direction.

MALLORY
Resistance Welding Data Book
Be sure that your engineering library includes this comprehensive reference to resistance welding practice, alloys and specifications. Write for your copy today.

P. R. MALLORY & CO., Inc., Indianapolis, Indiana • Cable Address—PELMALLO

man of the Ladies Entertainment Committee on whose account the meeting was called. Mrs. Thomas Jackson expressed her pleasure at seeing so many ladies present (22) and invited them all to gather in an adjoining room for a discussion of matters relating to the Ladies' Entertainment. The men continued their meeting on the veranda.

Judging from the enthusiasm shown at the Monday evening dinner meeting, the 1941 Annual Convention should surpass all others.

Much credit is due Mr. Barnes for arranging this worth while dinner meeting, to Mr. W. A. Terry for making it possible to hold the dinner in such pleasant surroundings, to Mr. Thomas for furnishing the members and guests with a map directing them to the Country Club, and to all the Philadelphia Section officers for their generosity in looking after the welfare of their guests.

SAN FRANCISCO

The final meeting of the San Francisco Section for the fiscal year was held at the Athens Athletic Club, Oakland, on Monday, May 26th. The Section was honored by the presence of Colonel G. F. Jenks, National President of the SOCIETY, and W. Spraragen from SOCIETY headquarters. Both Colonel Jenks and Mr. Spraragen gave brief résumés of the different phases of the SOCIETY activities and its plans for the future. Colonel Jenks also supplemented his remarks by a high spot review of how welding is assisting in the Ordnance Department in the fabrication of ordnance equipment, particularly in the savings of weight and improvement of the product.

The principal speaker of the evening was Mr. F. C. Fantz, Vice-President, Midwest Piping and Supply Co., Inc. Mr. Fantz gave a very interesting and instructive, illustrated lecture on the "Fabrication of Piping Systems by Welding," giving special reference to the part that the SOCIETY's codes played in this work.

SOUTH TEXAS

The South Texas Section held a regular meeting on May 27th at the Houston Engineers' Club, and Mr. Marvin Cook, a past-chairman of the Section, was in charge of the program for the evening. Mr. B. J. Davis of the Houston Pipe and Steel Company presented a motion picture of the laying of pipe lines in Iraq. Many interesting incidents were shown and discussed and highlights of the work were ably photographed. Huge trucks hauled twenty tons of pipe in 40-foot lengths across the barren country at twenty miles an hour. Crews completed as many as six miles of line per day under favorable conditions.

WASHINGTON

The following are the newly elected officers of the Washington Section for the year 1941–42: *Chairman*, R. B. Swope, Southern Oxygen Co.; *Vice-Chairman*, G. E. Knox, Bureau of Yards and Docks; *Secretary*, E. Brooker, U. S. Navy; *Treasurer*, R. F. Wood, care of Wm. M. Corse Chem. & Met. Engr. *Executive Committee* (1 year) R. B. Nation; (2 years) G. E. Meissner, H. L. Ingram, E. T. Lang, W. E. McKenzie, C. A. Trexel, G. F. Jenks.

Meeting dates for the forthcoming year are as follows: October 2, 1941, November 25, 1941, December 8, 1941, January 27, 1942, February 24, 1942, March 24, 1942, April 28, 1942.

WESTERN NEW YORK

The May meeting of this Section, the last business meeting of the season, was held May 16th, in the Hotel Buffalo.

Announcement of the unanimous reelection of all officers and directors for the coming year was made as follows: *Chairman*, Bud Trefts, Farrar & Trefts, Inc.; *Vice-Chairman*, George Schliecker, R. C. Neal Company; *Secretary*, Don Patterson, Federal Machine & Welder Co.; *Treasurer*, Bob Siemer, Allan Mfg. & Welding Co., Inc. *Directors:* J. K. Bard, John Bos, Bill Gordon, Jim Murray and Joe Dolan.

The speaker of the evening, Mr. Frazer, of the Carnegie-Illinois Steel Company, gave an enlightening talk on the welding and fabrication of stainless steels, together with a brief history of the development of these steels.

Welcomed at the meeting was a large group from the Air Preheater Company in Wellsville, New York, and hope was expressed that they will be able to attend other meetings of the Section in the fall.

Employment Service Bulletin

POSITION VACANT

V-100. Engineer to design flash, butt, seam and projection welders wanted by well-known resistance welder manufacturer. Applications should be sent directly to the AMERICAN WELDING SOCIETY, stating salary and experience. All members of the company's organization know of this notice.

V-101. Thoroughly trained Welding Engineer with experience in welding both structural steel and steel plate. Applicant must be able to instruct and supervise Arc Welders. He must be able to secure high quality workmanship at low cost. Submit full information regarding education, experience, age, references and salary desired with first letter.

SERVICES AVAILABLE

A-408. Arc Welder. Seeking better future in welding industry. Five (5) years of shop and field experience in tanks, pipes, frames, fabrication and assembly. Expert on industrial exhaust systems, Can weld in all positions, read blue-prints, and make estimates. Age 27, married, two (2) years of college. Prefer location in or around New York City. Will prove to be worthy of consideration.

A-409. Welder. Five months' experience and ten weeks of training. Training course sponsored at local high school by government. Capable of welding flat, horizontal, vertical and overhead. Also experienced on an electric drill press.

A-410. Arc welder desires position in Central or Southern U. S. or South America. Graduate of resident welding school. One year's experience welding in all positions. Can read blue-prints and knows welding symbols. Now enrolled in National Defense drafting course.

A-411. Metallurgical Engineer, B.S. and M.S. Experienced in aircraft, pressure piping and pressure vessel (including Unionmelt) welding. Desires position as welding engineer on production work.

A-412. Combination welder, thoroughly experienced, desires change with opportunity for advancement. Sixteen years' experience in both arc and gas welding, a specialist in extra heavy maintenance welding of heavy machinery. Conversant with all common metals and various alloys, their fabrication, welding procedures, set-up, layout and design. Have had considerable experience with change-over design from cast iron to steel. Am 38 years of age, good education specializing in welding, at present employed as welding supervisor which position has been held for the past six years. No objection to travel either domestic or foreign.

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List of New Members

May 1 to May 31, 1941

BOSTON

O'Rourke, Frank (C), Massachusetts Welding Co., 79 Clapp St., Corner of Mass. Ave., Boston, Mass.
Tucker, Elias (C), Tucker Welding Supply Co., 1718 Commonwealth, Boston, Mass.
Winsor, Allen P., Jr. (C), New Bedford Boiler & Machine Co., P.O. Box 650, New Bedford, Mass.

CANAL ZONE

Nuckolls, Emmett B. (C), P.O. Box 279, Diablo Hts., Panama, C. Z.

CHICAGO

Gwyn, C. B., Jr. (B), Fansteel Metallurgical Corp., North Chicago, Ill.
Kugler, K. G. (C), 1605 Atchison Ave., Whiting, Ind.
Pickhaver, L. G. (C), General Electric Co., 849 So. Canal St., Chicago, Ill.
Rainey, Thomas G. (D), 7450 Luella Ave., Chicago, Ill.
Schumacher, Geo. T. (D), 114 Harding St., Elgin, Ill.
Sheldon, Henry C. (D), 220 Clinton Ave., Oak Park, Ill.

CLEVELAND

Judge, J. D. (B), Babcock & Wilcox Co., Barberton, Ohio.
Lehtinen, Francis J. (C), American Bureau of Shipping, 660 Rockefeller Bldg., Cleveland, Ohio.

COLORADO

Reynolds, H. E. (D), Thompson Pipe & Steel Co., 3517 Delgany, Denver, Colo.

HAWAII

Morgan, J. Grant (C), 288 Wainani Way, Honolulu, T. H.

LOS ANGELES

O'Brian, Wm. (C), R. W. Hunt Co., 1151 So. Broadway, Los Angeles, Calif.

MARYLAND

Hall, Theodore (C), Overhill Rd., Catonsville, Md.

MILWAUKEE

Gilbert, Verl L. (C), 1836 N. 7th St., Sheboygan, Wis.
Kells, Donald G. (D), 1501 S. 33rd St., Milwaukee, Wis.
Yates, Charles S. (C), 1321 Manitoba Ave., South Milwaukee, Wis.

NEW YORK

Crum, Frank J. (C), American Bureau of Shipping, 47 Beaver St., New York, N. Y.
De Meo, Joseph (D), 103-24—34th Ave., Corona, N. Y.
Johnson, Wallace C. (B), Pine Terrace West, Shore Hills, N. J.
Scott, N. Dan (D), 592 Morris Park Ave., New York, N. Y.
Swann, Ralph G. (D), 2216 Ryder Ave., Brooklyn, N. Y.

NORTHERN NEW JERSEY

Adams, Walter F. (D), 32 Rutland Ave., Kearny, N. J.
Alberino, James J. (D), 103 Wilkinson Ave., Jersey City, N. J.
Brunner, George A. (C), Chicago Bridge & Iron Co., 119 Long Ave., Hillside, N. J.
Cavanaugh, Frank J. (D), 420 Union St., Jersey City, N. J.
Critchett, N. W. (D), 6 Banta Pl., Irvington, N. J.
Fielding, Edmund G. (C), 517 W. Jackson St., York, Pa.
Harkrader, C. Ellison (C), Welin Davit & Boat Corp., 500 Market St., Perth Amboy, N. J.
Kruic, Paul P. (D), 293 Varick St., Jersey City, N. J.
Lasiewski, Anthony V. (D), 118 Wayne St., Jersey City, N. J.
Misciagno, Leonard (D), 83 Ocean Ave., Jersey City, N. J.
Olson, Albert M. (D), 627 Adams Ave., Elizabeth, N. J.
Rainey, John Carl (D), 305 Fairmount Ave., Apt. 202, Jersey City, N. J.
Slaughter, William Irving (D), 12 Meadow St., East Orange, N. J.
Wells, Alfred R. (D), Lion Welding Co., 570 Lyons Ave., Irvington, N. J.

NORTHERN NEW YORK

Longdyke, James E. (D), 1730 Watt St., Schenectady, N. Y.

OKLAHOMA CITY

Comer, Kenneth L. (D), 118 E. Ninth St., Oklahoma City, Okla.
Seelig, Don (F), Campus Fire Station, Stillwater, Okla.

PEORIA

Le Tourneau, R. G. (A), R. G. Le Tourneau, Inc., Peoria, Ill.

PITTSBURGH

Rice, John M. (B), Grant Bldg., Pittsburgh, Pa.
Ullmer, Val G. (B), 131 Sampson Ave., #5, Pittsburgh, Pa.

ROCHESTER

Plane, Carl (D), Sallen Hotel, Palmyra, N. Y.
Quagley, Samuel T. (D), 1722 Chili Ave., Rochester, N. Y.

ST. LOUIS

Meier, E. F. (C), 2603 Louis Ave., Brentwood, Mo.

SAN FRANCISCO

Klistoff, Al. (D), 1464 Rhode Island St., San Francisco, Calif.
Middlehurst, D. J. (C), Victor Equipment Co., 844-50 Folsom St., San Francisco, Calif.
Moore, Arthur U. (D), 346 Hermann St., San Francisco, Calif.
Norris, Walter T. (C), American Inst. of Steel Const., 303 Sharon Bldg., San Francisco, Calif.
Redhead, John J. (D), Western Pipe & Steel Co., Mills Bldg., San Francisco, Calif.

SOUTH TEXAS

Murray, T. L. (D), 3309—11th St., Port Arthur, Texas.
Savoy, L. M. (D), 6728 Ave. L, Houston, Texas.

TULSA

Pickett, Bill (C), National Cylinder Gas Co., 311 E. 3rd St., Tulsa, Okla.

WESTERN NEW YORK

Bradley, Holbrook (C), Welding Engineering Sales Corp., 1 W. Genesee St., Buffalo, N. Y.

YORK—CENTRAL PENNA.

Buchanan, Blair G. (C), Milroy, Pa.
Rahm, Harry A. (D), 501 Locust St., Lancaster, Pa.

YOUNGSTOWN

Rostetter, John D. (C), 839 Fifth Ave., Youngstown, Ohio.

NOT IN SECTIONS

Kahrs, William A. (D), 21 East Simmons St., Charleston, S. C.
Millican, A. J. (D), 599 W. Sherman St., Paris, Texas.
Mitton, George (D), Planta de Hielo, El Higo Ver., Mex.
Wilson, G. E. (B), Clinton Bridge Works, Clinton, Iowa.